Methods of Electronic Audio Surveillance

By

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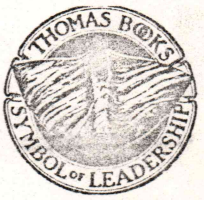

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Chapter 1

BASIC ELECTRONICS

SINCE THE BASIC laws of electricity are the foundation for a study of electronic methods of investigation, it is advised that the technician be well acquainted with them. It is outside the scope of this work to present a complete treatise on electrical laws and circuits. Instead, this chapter is presented in the way of a refresher to cover some of the more widely used principles that will be discussed later. Electrical safety is held to be of prime importance. The student should be conversant with first aid and electric shock resuscitation *before* he attempts to perform any of the operations discussed.

BASIC ELECTRICITY

Electrical Fields

The field is the basis for the action of electricity. It is necessary to have an idea of just what a field is, in order to understand electrical effects. Two important properties are found in an electrical field—magnitude and direction. The field exercises a force against a particle surrounded by it. Magnitude is the amount of force present, and direction is the path that the particle will travel, depending upon the direction of the field. If a magnet should be brought into a field it will be affected by the force of the field.

The world is composed of various substances called elements which are, in turn, composed of negative electrical charges called electrons and positive charges called protons. A body which contains an equal amount of positive and negative electricity may be termed "in equilibrium." However, if the body has an excess of either charge, it is known as a "charged particle." Lines

of force exist between two charged bodies and tend to repel the bodies if they are like charged or attract each other if they are charged in an unlike manner. This whole process is termed "the electrical field," and it extends in all directions around every charged body. (See Figure 1-1.)

The drift of electrons along a conductor in a given direction is called the electric current. Current flows from negative pole to positive pole. Certain materials do not permit the free flow of electrons. These materials are called insulators or dielectric substances. That material which facilitates the flow of charges is known as a conductor, while material that does not permit charges to flow freely is called a nonconductor. All materials are conductors under certain circumstances. Insulating materials are rubber, plastic, shellac, porcelain, quartz, nylon and air. Dry wood, cotton and linen are known as semiconductors. Good conductors are found among the metals, in the acids and in moist earth. See Table I for comparative conductive values.)

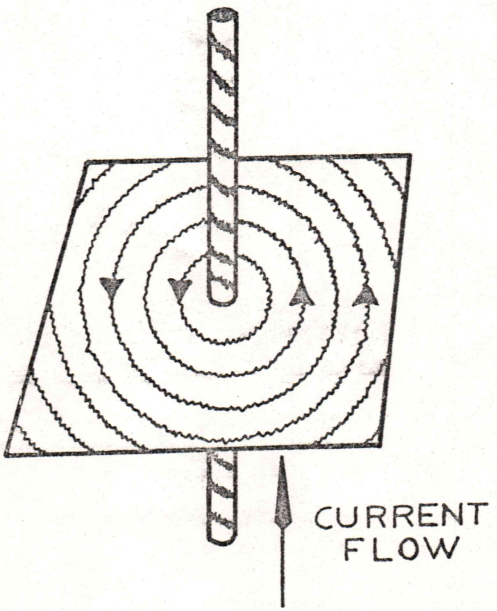


Figure 1-1. Magnetic field around current-bearing wire.

TABLE I

PROXIMATE INSULATION BREAKDOWN VOLTAGES

Substance	*Breakdown Voltages*°
Air	1,980-2,280
Bakelite (paper base)	65,000-75,000
Formica	45,000
Glass (ordinary)	20,000-25,000
Lucite	48,000-50,000
Paper	12,500
Polyethylene	100,000
Porcelain	4,000-10,000
Pyrex	33,000
Rubber	45,000

° In volts per 0.1 inch.

Conductivity

Conductivity, measured in μmhos, is a term which describes the ability of a conductor to carry an electric current. The greater the degree of conductance, the higher current the conductor will bear. Aluminum has high conductivity, as have silver and copper. The force that causes current to travel in a conductor is known as the electromotive force (emf) and is measured in volts. It is produced either in an electric cell by chemical action on different kinds of metals or in an electrical generator by a combination of mechanical and magnetic forces. This is the kind of power that is provided to houses and stores. Current flow occurs in two types: direct current (d-c), which is a series of electrons constantly flowing in the same direction, in a series chain, furnished by batteries and some generators; and alternating current (a-c), an emf which flows first in one direction and then in the other. These current reversals may take place at varied rates per second, the most common in North American household use being 60 cycles per second (cps or Hz). This example of the number of cps is termed the "frequency of alternation."

Electric current flow is measured in amperes (amps) or in a lighter flow in milliamperes (milliamps or ma), one of which represents 1/1000 ampere. An amp is equal to 6.28×10^{18} electrons per second past a given point in an electrical circuit.

Resistance

A substance which has great conductivity is described as

offering low resistance to electron flow. The metal silver has very low resistance, while carbon has proportionately greater resistance. Some alloys of cupro-nickel and iron-manganese have many times the resistance of ordinary copper. When a device is placed in an electrical circuit to cause an increase in resistance, it is known as a resistor and is measured in ohms (Ω). Some are fixed in value and others are variable. A variable resistor may be known as a rheostat or a potentiometer and may be wire-wound or of molded composition. Small diameter wires carry reduced amounts of current due to higher resistance than larger diameter wires which have correspondingly less resistance. The analogy of the water pipe carrying water is a convenient parallel, since the smaller diameter pipe offers more resistance to the flow of water than the larger diameter water pipe, just as in the wire illustration above. Length of the conductor is important, since a length of wire ten feet long offers twice as much resistance to a current as a wire of the same diameter which is only five feet long. (See Table II.)

TABLE II

RESISTANCE OF METALS COMPARED TO SILVER

Aluminum	1.74
Carbon	215
Copper	1.06
German silver	20
Mercury	59
Silver	1.00
Soft iron	6.00
Platinum	6.15

Ohm's Law

In an electrical circuit the values of resistance, voltage and current are all dependent upon each other. There exists a law, called Ohm's law, by which caculations may be made to determine relationships where two of the values are known. The law is expressed as follows:

> Current flowing through a circuit is directly proportional to the applied emf and inversely proportional to the resistance.

In equation form

$$I \text{ (amps)} = \frac{E \text{ (volts)}}{R \text{ (ohms)}}$$

I = current in amperes
E = emf in volts
R = resistance in ohms

This is the basic equation and can be varied to reveal the following:

The voltage necessary to force a particular amount of current through a resistance of known value.

$$E = I \times R$$

The resistance that will suppress the current to a particular amount under influence of a known amount of emf in volts.

$$R = \frac{E}{I}$$

Joule's Law

When Joule's law is combined with Ohm's law, an extremely useful combination results:

$$W = I^2 \times R$$

W = power in watts

Now the following formulae which result from the combination may be universally applied in the field of electronics:

$$I = \frac{E}{R} \qquad R = \frac{W}{I^2}$$

$$I = \frac{W}{E} \qquad E = I \times R$$

$$I = \sqrt[2]{\frac{W}{R}} \qquad E = \frac{W}{I}$$

$$R = \frac{E^2}{W} \qquad E = \sqrt[2]{W \times R}$$

$$R = \frac{E}{I} \qquad W = E \times I$$

$$W = I^2 \times R$$

$$W = \frac{E^2}{R}$$

Remember that all quantities must be converted to *volts, ohms* or *amps;* other quantities must first be converted by noting the following commonly used prefixes:

micro—one-millionth (μ)
milli—one-thousandth (m)
Kilo—one thousand (K)
mega—one million (M)

As an example, 1 millivolt (mv) equals 1/1000 volt, and 5 microvolts (μv) equal 5/1,000,000 volt.

Resistance in Series and Parallel

Apparatus may be connected in two ways—in series and in parallel. When components are connected in series, the same current is drawn through each component. The resistance of each component controls the voltage drop across the section. If one section has three times the resistance of the other section, the voltage drop will amount to three times as much. In this type circuit, the sum of the resistances amounts to the total resistance of the circuit. (See Figure 1-2.)

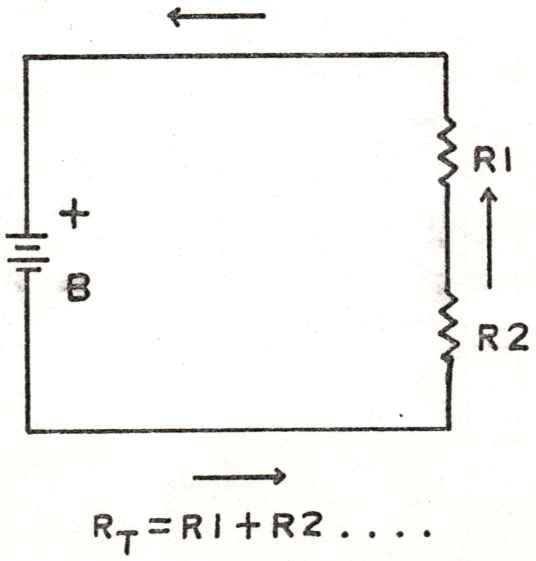
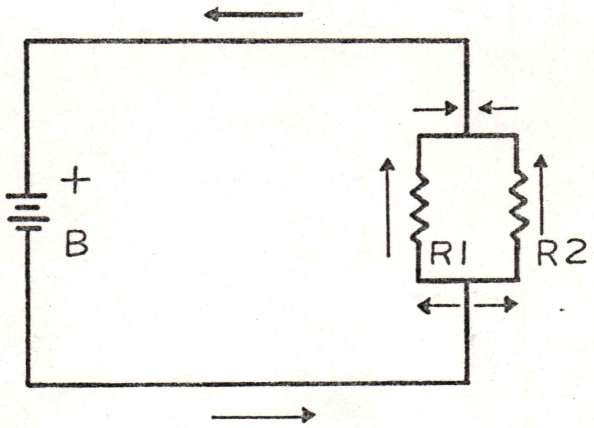


Figure 1-2. Series-resistance circuit.



$$R_T = \frac{R1 \cdot R2 \ldots}{R1 + R2 \ldots}$$

Figure 1-3. Parallel-resistance circuit.

In parallel circuits, the components are arranged in a branched affair. The voltage across each section is the same and is the same as the battery's voltage. Current supplied to this circuit by the power supply, is the sum of the current consumed by the sections. (See Figure 1-3.)

Often complicated circuits are arranged in series-parallel, but they may be easily reduced to a more simple form by finding the equivalent resistance and treating the whole as a series circuit. (See Figure 1-4.)

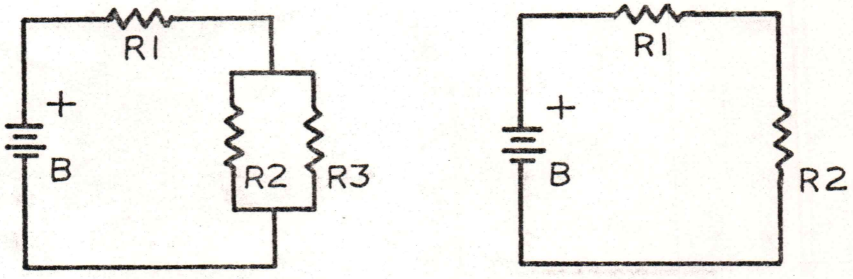


Figure 1-4. Series-parallel circuit and its equivalency.

Capacitance

Capacitance is the property of storage of electricity and is possessed by components called capacitors or condensers. It is measured, fundamentally, in units called farads, but usually measured in microfarads (μfd) or micromicrofarads ($\mu\mu$fd), also known as picrofarads (pfd). A microfarad is one-millionth of a farad, and a micromicrofarad is one-millionth of a microfarad. When current flows through a capacitor, which consists of two metallic plates close to each other but separated by a dielectric material such as air or waxed paper, the voltage of the power supply appears across the terminals of the capacitor, by movement of electrons from plate to plate. Thus the capacitor builds up a charge which is stored inside, even after the circuit is opened. Capacitors store charges of electricity which, after circuits are opened, may discharge to ground through the technician's body. With larger capacitors, such as those found in radio transmitting stations and in television receivers, a great potential danger exists. It is a good policy to ground all capacitors with a screwdriver before probing around in their vicinity. The larger the capacitance, the greater the danger. Capacitors have a limit to the amount of high voltage they are capable of withstanding. This figure is called the breakdown voltage. Sustained voltages, or surges, which significantly exceed the rated breakdown voltage will cause their destruction.

Capacitors in Series and Parallel

Series and parallel circuits, applied to capacitors, have the same meaning as when they are applied to resistances. Capacitors connected in parallel (see Fig. 1-5) have a total capacitance of the sum of the individual capacitances, as

$$C_{total} = C_1 + C_2 + C_3 \ldots$$

In the event that the capacitors are connected in series, however (see Fig. 1-6), their total capacitance is lower than any of the unit capacitances as

$$C_{total} = \frac{C_1 \times C_2}{C_1 + C_2}$$

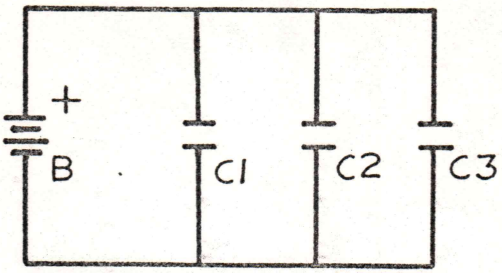


Figure 1-5. Parallel capacitance circuit.

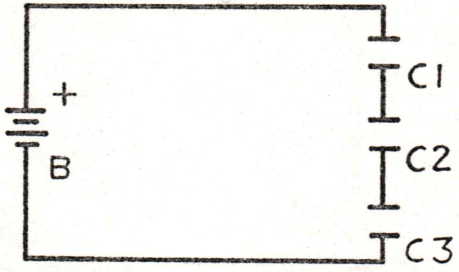


Figure 1-6. Series capacitance circuit.

Inductance

It is observed that when current flows through a wire it causes magnetic effects, as can be seen when a compass is held near the wire. The magnetic effect is stronger when the current is high. When a loop is made in the wire, the current causes an even stronger effect than it did with the straight wire. This property is termed "inductance" and is the strength of the field proportional to the intensity of the current flow. When an iron core is placed inside the loop, the field becomes even stronger. When current is varied in intensity through the loop, a voltage appears across the loop terminals, exclusive of the voltage causing the current. This voltage has been induced and is the reason that the inductor has been so named—from its self-inductance. This principle is employed in the telephone induction coil as a form of sound pickup.

Transformers

To lower or raise the voltage of an a-c circuit a device called a transformer is employed. It transforms one voltage to another

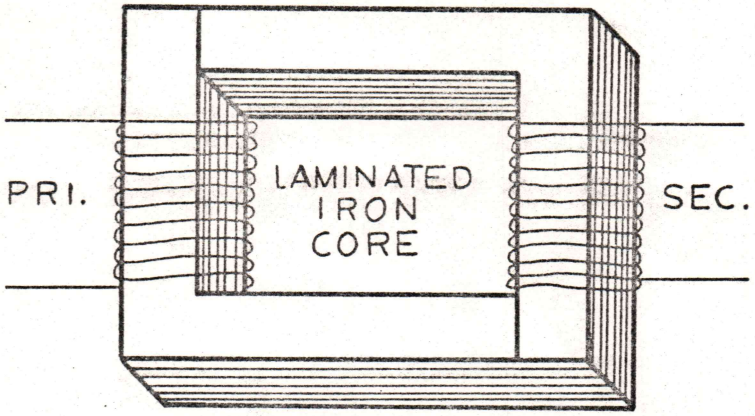


Figure 1-7. Simple transformer.

and is composed of two coil windings generally on an iron core. (See Figure 1-7.)

The core serves to cause the magnetic field set up in the primary coil to flow without losses into the secondary coil. An a-c line is connected to the primary, and the secondary coil is attached to a load. Voltages are induced in the secondary coil by the varying lines of force in the primary coil. (See Figure 1-8.)

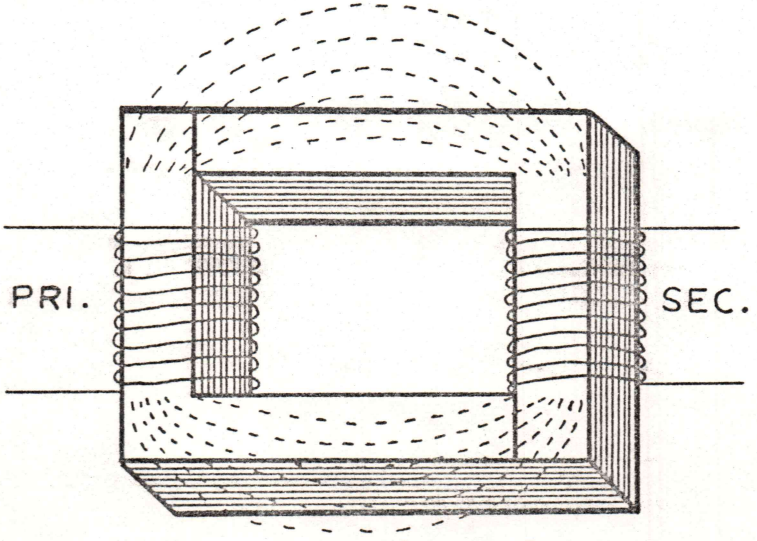


Figure 1-8. Lines of magnetic force.

The difference between the incoming and outgoing voltages is regulated by the ratio of turns in the primary coil to those in the secondary coil. Transformers are also used as impedance matching and line isolation devices.

Impedance

In circuits containing both reactance (the variable opposition offered by a capacitor, depending upon the frequency of the current and the capacitance of the condenser) and resistance, the opposition characteristic is called impedance, instead of resistance. It also uses the ohm as a unit of measure. Ohm's law can be applied to impedance circuits, as it is in cases of resistance. The formulae are

$$I = \frac{E}{Z}$$

$$E = I \times Z$$

$$Z = \frac{E}{I}$$

E = emf in volts
I = current in amps
Z = impedance in ohms

In most circuits employed in audio and radio, certain specific impedance values are necessary for efficient operation. This is accomplished by regulating the load impedance, generally by use of what is known as a matching transformer, to the proper value required in the circuit to be matched. This process is termed "impedance matching" and will be discussed in more detail in later chapters with regard to matching inputs and outputs of amplifiers, radios and recorders.

Measuring Electrical Flow

Instruments that measure current flow are called ammeters. They are connected in series with the current source and the circuit. (See Figure 1-9.)

Measurement of heavy currents is made possible by shunting the meter with heavy conductors to allow only a minor portion of the current to flow through the meter itself. Measurement of

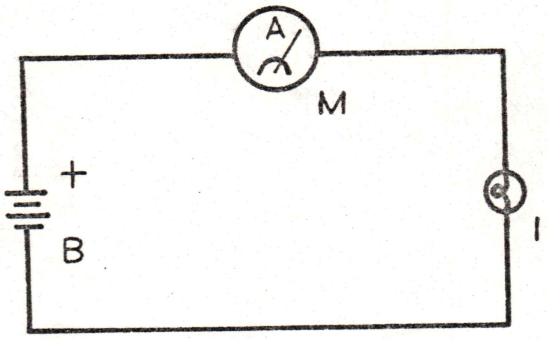


Figure 1-9. Ammeter in circuit.

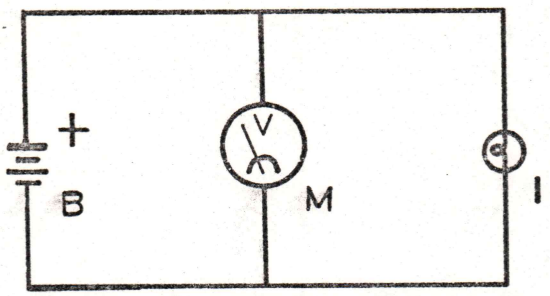


Figure 1-10. Voltmeter in circuit.

voltage is accomplished by use of a voltmeter, which is placed across the circuit in parallel. (See Figure 1-10.)

An ammeter must never be used across power source terminals since it provides a direct short and will damage the power source and possibly the meter. Voltmeters are essentially high-resistance ammeters, since their basic construction involves placing a high resistance in series with an ammeter movement. The sensitivity of a voltmeter is expressed as the resistance per volt to be measured. If the meter is to be used on circuits from which it should not draw much current, for accurate reading, it should have a resistance in the vicinity of 20,000 ohms/volt. Inexpensive voltohmmeters may vary about 1,000 ohms/volt and are generally quite inaccurate. Except under critical conditions, resistance is generally measured by placing a battery in series with a

resistance-calibrated voltmeter and reading directly in ohms. For higher accuracy a comparison resistance check is made against a calibrated variable resistance or a Wheatstone bridge.

Frequency

The wave of an a-c current completes a quantity of cycles per second. The number of cycles per second (Hz) determines the frequency of the wave. Frequencies employed for purposes of communication are separated into two large groups: audio frequencies (a-f) and radio frequencies (r-f). Response to audio frequencies by the human ear vary from about 15 to 20,000 Hz. Speech frequencies fall generally between 200 and 2,500 Hz. while the range of an organ is between 16 and 5,000 Hz. The fundamental notes of an instrument, such as a flute, go as high as about 4,000 Hz. The actual sounds of speech and music are composed of rather complicated combinations of irregular and changing shape patterns called harmonics or overtones. They are multiples of the fundamental frequency and give different sound to those same frequencies from different sources. The average human ear responds well to sounds in the vicinity of 2,000 Hz and misses most of the sounds above 15,000 Hz. Reproducers such as loudspeakers, earphones and telephone receivers utilize these audio frequencies to transfer audible sound to the ear.

From 20,000 Hz (20 kiloHertz) to over 30,000,000,000 Hz (30,000 megaHertz) exist what we term the "radio frequencies." Based on the fact that the different groups of frequencies included in this spectrum exhibit divergent effects, the radio frequencies are generally classified in broad groups or bands. These bands are shown in Table III.

TABLE III

Band Classification	*Frequency Range*
Very-low-frequency (v-l-f)	10 kHz to 30 kHz
Low-frequency (l-f)	30 kHz to 300 kHz
Medium-frequency (m-f)	300 kHz to 3,000 kHz
High-frequency (h-f)	3,000 kHz to 30 MHz
Very-high-frequency (v-h-f)	30 MHz to 300 MHz
Ultra-high-frequency (u-h-f)	300 MHz to 3,000 MHz
Super-high-frequency (s-h-f)	3,000 MHz to 30,000 MHz

Relationship of Radio Frequency to Wavelength

As r-f current flows through the antenna of a transmitter, radio waves are radiated in all directions in a manner similar to the concentric rings formed when a stone is thrown into a pool of water. These radio waves travel at the speed of light—186,000 miles per second, which is equivalent to 300,000,000 meters per second. Since the radio waves are produced by placing high-frequency (h-f) a-c on an antenna wire, the frequency of the radio wave will be the same as the frequency of the h-f a-c. The relationship is shown below:

$$\text{Wavelength } (\lambda \text{ meters}) = \frac{300{,}000{,}000 \text{ (meters per second—velocity)}}{\text{Frequency (Hz)}}$$

where λ = wavelength in meters
f = frequencies in kiloHertz

or

$$\lambda = \frac{300}{f} \quad \text{and} \quad f = \frac{300}{\lambda}$$

where λ = wavelength in meters
f = frequency in megaHertz

These matters are of some concern in the adjustment of antenna length.

Radio Frequency Circuits

Elements arranged so that they produce a particular desired effect on a radio circuit are called tuned circuits. Without such arrangements, in collaboration with vacuum tubes and semiconductor devices, modern radio would be impossible since their tuning to frequency depends on such tuned circuits. In receivers these circuits function to select signals for reception and also to reject unwanted signals. This capability of a receiver is termed its "selectivity" and depends completely on the proper functioning of tuned circuits. Set sensitivity is critically reduced in the event of failure or malfunction of any of the tuned circuit parts. Transmitters are so dependent upon their proper operation that set range is reduced, or the transmitter becomes inoperative if failure of a tuned radio frequency (t-r-f) stage occurs. In the trans-

mitter the whole process of r-f power generation and amplification depends upon the performance of the t-r-f stage, in addition to the rigid regulation of frequency stability.

Vacuum Tubes

A vacuum tube is a series of metallic elements enclosed in an evacuated glass envelope, which is heated by passage of a current through the cathode element. The basis for operation of all types of vacuum tubes is the attraction between negatively charged electrons and an isolated, positively charged body in the area of the electron emitter or cathode. The positively charged plate element surrounds the emitter and the electrons flow from negative to positive pole. The most simple type of vacuum tube is named a diode. It consists of two elements, the cathode and the plate. (Refer to Figure 1-11.) When a positive voltage is put on the plate, current flows through the tube. If negative voltage is impressed on the plate, no current flows through the tube. If electrons flow through the tube, then current flows through the circuit since the diode serves as a conductor when plate voltage is positive and as a nonconductor when plate voltage is negative. This type of tube is capable of two important jobs: detection and rectification.

A triode tube differs only in the addition of another element called the grid. This grid, when biased by a negative voltage, impedes the flow of electrons from cathode to plate and consequently controls the plate current. This method of controlling the tube's output is, in many cases, used as a type of volume control.

The tetrode was next developed by adding a screen grid near the plate. This screen grid assists the plate in attracting electrons from the cathode by operating at a positive voltage and reduces the interelectrode capacitance by being bypassed to the negative side of the circuit through a screen-bypass capacitor. The tetrode is capable of higher amplification factor and greater power sensitivity than the triodes and is used widely in r-f stages of radio transmitters and receivers.

When difficulty was experienced with a secondary emission—that characteristic of tetrodes for the screen to attract more than

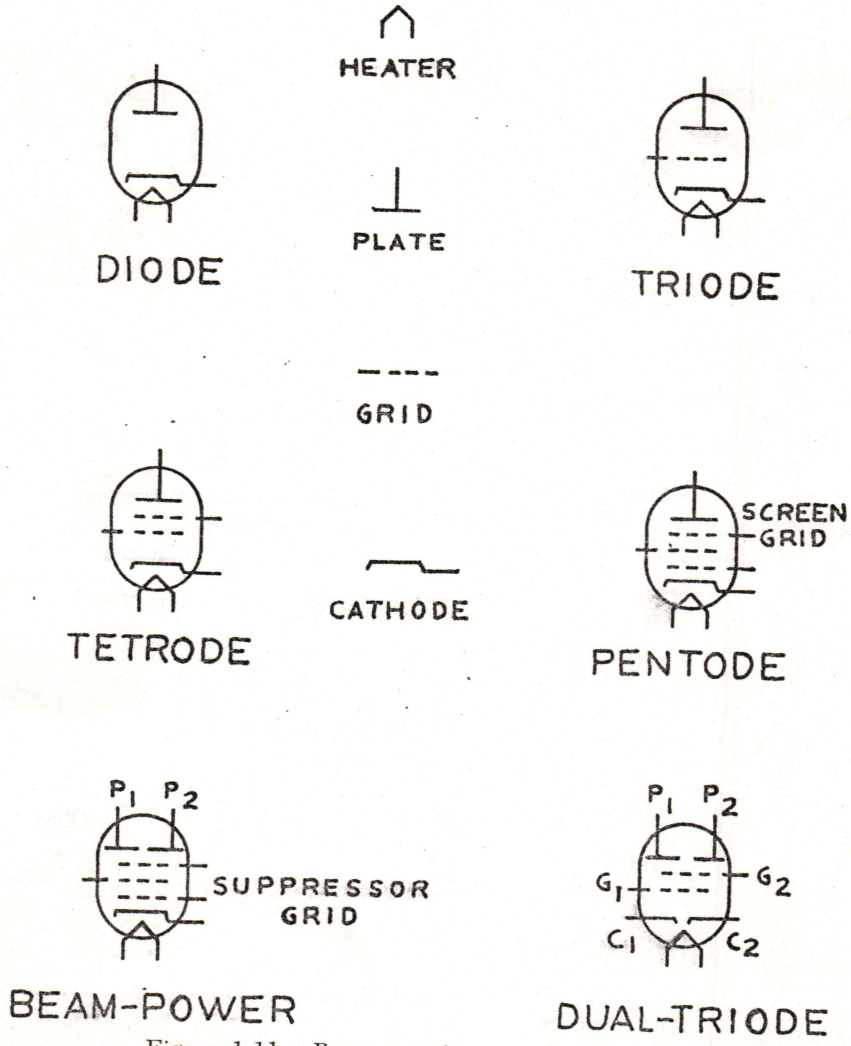


Figure 1-11. Representative vacuum tube types.

its share of electrons, causing distortion and lower amplification—the pentode was developed by adding a third grid called the suppressor grid. The name comes from the fact that it prevents the flow of secondary electrons to the screen. The addition of two beam-bending plates brought the beam-power tube into existence, greatly increasing the power output efficiency of the tube. There

are many other types of tubes, most of them being complex types which combine the electrodes of two or more tubes in a single envelope. There are twin-triodes, diode-triodes, diode-pentodes, triode-pentodes, pentagrid-converters (contains five grids and takes the place of two separate tubes), duplex-diodes, and duplex-diode pentodes.

Semiconductors

Semiconductor materials employ the principle of flow of electrons through a solid (hence, "solid-state") rather than through a gas or vacuum state as do vacuum tubes. All materials, broadly speaking, fall into one of three classifications—conductors, semiconductors or insulators. Their classification thus is based on the degree to which they conduct electricity. Most often used in semiconductor devices are the elements germanium and silicon. Germanium has the characteristic of greater electrical conductivity and is, for this reason, used in the majority of low and medium power transistors and diodes. Generally, silicon is used in high-power semiconductor devices and is especially valuable because of its ability to withstand greater ambient operating temperatures. A new compound—gallium arsenide—combines the primary desirable characteristics of both germanium and silicon and is being used to supplant the others to an increasingly great degree.

This ability of a substance to conduct current is directly proportional to the number of free electrons retained by the substance. Such conductors as silver and copper have excess free electrons and low resistivity (approximately a few millionths of an ohm/centimeter). On the other hand, glass, nylon and rubber are examples of insulators having resistivities of the order of several million ohm/centimeter. In the middle ground, between these limits, will be found the semiconductors. While pure germanium has a resistivity of 60 ohms/centimeter, it is employed with certain controlled amounts of impurities which enhance the flow of electrons at room temperatures. The crystalline structure of semiconductor materials resembles a lattice network wherein the outer or valence electrons of atoms are bound in electron-pair bonds to the electrons of adjoining atoms. In this state they are

relatively stable and would serve as inefficient conductors were it not for the addition of trace amounts of other elements which alter the atomic structure so that one more valence electron is held by the atom. Only slight excitation is required to separate this unbalanced electron. Impurities, such as antimony and arsenic, are added in trace amounts (such as 1:10 million) to silicon and germanium resulting in an n-type (negative) material. By the addition of aluminum, gallium or indium to the material, the semiconductor will be found to possess one less valence electron in its lattice structure, resulting in a p-type (positive) material. A vacancy or "hole" in the latticework structure appears with this kind of semiconductor material, and an electron from an adjoining pair may gain enough energy to break its bond and move through the lattice and fill the "hole." These "holes" enhance the flow of electrons through the semiconductor causing a decrease in its resistivity. These negative and positive materials may be joined together in a kind of sandwich arrangement, termed "p-n junctions," in which an interaction takes place at the interface of the two materials. This is based on the excess of electrons in the n-type material and the presence of "holes" in the p-type material. At the junction free electrons from the n-type substance diffuse and recombine with the holes in the lattice of the p-type substance. Conversely, holes in the p-type lattice may diffuse and combine with free electrons in the n-type substance. This activity is enhanced by a small, unmeasurable, space-charge region as the n-type substance acquires a small positive charge and the p-type substance gains a slight negative charge.

If a p-n junction is biased by a negative flow of electricity on its *positive* side, little flow of current takes place because the charge is repelled in a process known as reverse biasing. Conversely, if the p-n junction is biased by a negative flow of electricity on its negative side, heavy current flow takes place in a process termed "forward biasing." The application of excess voltage (bias) in either direction must be limited because heavy currents and associated high-operating temperatures generated by such states (beyond the component's rated capability) may cause breakdown and destruction of the semiconductor.

By producing an n-p-n "sandwich" it is possible to bias negatively the left side n-type substance while reverse-biasing the p-type material at the same time to provide a high-resistance output circuit and concurrent power gain in this example of the amplification capability of a transistor. P-n-p devices function similarly, although the polarity of the bias voltages are reversed and the flow of the electron current is in the reverse direction from that of the n-p-n type semiconductor device.

The simplest form of semiconductor is the diode which is a p-n device such as was discussed earlier. In this case the negative (n) electrode is termed the "cathode" and the positive (p) electrode is named the "anode." (See Figure 1-12.)

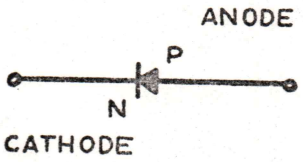


Figure 1-12. Semiconductor diode.

Since current is conducted more efficiently in one direction than the other, the junction diode serves as a rectifier wherein electron current of an a-c signal flows freely during the positive half-cycle but little or no current is conducted during the signal's negative half-cycle. Silicon rectifiers are found in wide usage and are capable of handling rated current flow from a fraction of an ampère to over 40 amperes, at voltages ranging to over 800 volts.

By arranging two p-type and two n-type semiconductor substances in series a device known as a gated switch or (silicon) controlled rectifier is formed. When biased in the reverse direction the device behaves as a conventional diode, whereas biasing in the forward direction results in functioning as a combination electronic switch and rectifier in series. Special diodes known as tunnel or Esaki (after the inventor) diodes are used for high-frequency amplification, detection, switching and pulse generation. (See Figure 1-13.)

When a second junction is provided the semiconductor diode,

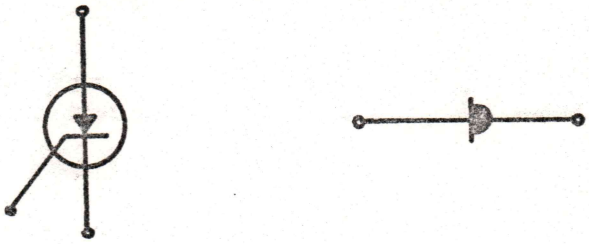


Figure 1-13. Gated switch (1) tunnel diode (r).

in order to develop voltage or power amplification, the device known as the transistor is produced. These three critical paths are termed "the emitter," "the collector" and "the base." Ordinarily, the emitter-base junction is forward-biased, while the collector-base junction is reverse-biased. N-p-n transistors utilize a flow of electrons from the emitter to the collector, while in the p-n-p transistor the electrons flow from the collector to the emitter. Electron flow is always opposite to the direction of the arrow used to show the emitter lead. (See Figure 1-14.)

The transistor's emitter polarity is shown by the first initial of its name. Thus, the n-p-n transistor's emitter must be negatively biased. The collector and base polarity of each type of transistor is opposite to that of its emitter. Transistors are especially suited for amplification, oscillation and frequency conversion. They consume relatively little current, require lower voltages, occupy small physical area, switch rapidly, require no "warm-up" time and are generally much more efficient than their vacuum tube counterparts in equivalent circuits. With the continuing development

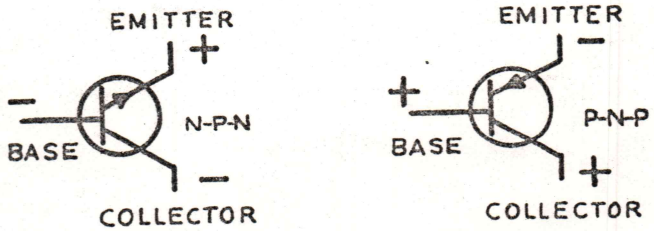


Figure 1-14. Transistor types.

of solid-state devices the vacuum tube is rapidly becoming obsolescent in industrial applications.

Grounding

Study of any electrical literature reveals mention of ground and ground potential. This does not necessarily mean that the actual connections are directly to an earth ground, but that an earth ground could be made at that place in the system without causing any disruption of the circuit. It also shows where common parts of the circuit are united electrically, by use of ordinary ground symbols rather than running a ground buss. The meaning of ground potential is that there is no voltage or difference of potential between that point in the circuit and the earth.

Symbols

Abbreviations are employed by all the technical fields to express parts of circuits in a kind of shorthand. Circuits are constructed on paper by connecting various symbols together in a schematic diagram. An electronic technician can determine as much by examining a circuit diagram of the device he is studying as the meteorologist can observe by scanning a weather chart. Symbols employed in audio, radio and telephony are found next, at the close of this chapter, in Figure 1-15. Complete familiarity with all of these symbols may be considered a prerequisite to full understanding of circuits encountered in electronic investigation.

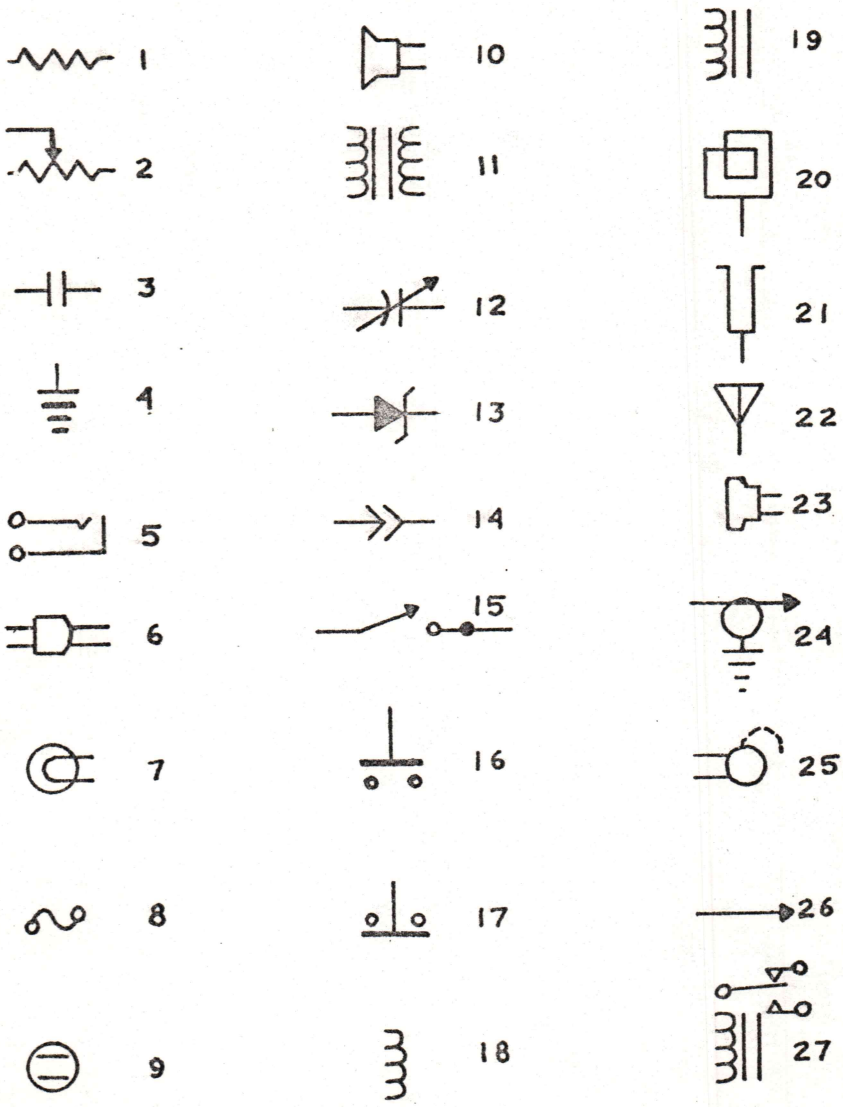


Figure 1-15. Electronic symbols: (1) fixed resistance; (2) variable resistance; (3) capacitance; (4) ground; (5) single-ckt jack; (6) plug; (7) pilot lamp; (8) fuse; (9) socket; (10) speaker; (11) transformer; (12) variable capacitance; (13) zener diode; (14) plug-jack connection; (15) SPST switch; (16) push-button switch, N.O.; (17) push-button switch, N.C.; (18) coil; (19) choke; (20) directional antenna; (21) dipole antenna; (22) antenna; (23) microphone; (24) shielded coaxial cable; (25) earphone; (26) lead to connection; and (27) relay.

Chapter 2

AUDIO SYSTEMS

AUDIO SYSTEMS ARE employed in motion pictures, phonographs, public address systems, radios, recorders and telephone systems and provide the basis for an understanding of electronic investigation devices. Their comprehension requires an understanding of the physical nature of sound.

GENERAL ANALYSIS OF SOUND

An analysis of sound and its transmission is prerequisite to the application of basic principles of audio systems and is initiated by a brief look at the necessary factors applying to voice transmission. From a physical standpoint, sound is an atmospheric disturbance producing an effect on the ear. Sound is also the result of the setting in motion of molecules of air, so that the ears respond by relaying the message to the brain. Sound can consist of noise, speech or music, all of which encompass similar principles of transmission. Interpretation and discrimination between these signals are work performed by the brain.

As an illustration of air as the transmitting medium, we may observe that a bell ringing inside an inverted bell jar sounds to us almost as if it were ringing outside the jar, but when the air is evacuated from the jar and the bell is ringing in a vacuum, we hear no sound. In this case, the medium has been removed.

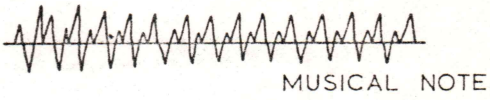
Basic Sound

Gently striking an accurately built tuning fork causes the most basic type of sound. When the prongs of the fork have commenced to vibrate, they move back and forth rapidly. When the prongs move forward, they cause a piling-up or increase in

air pressure of the air in front of them, also termed a "condensation." As the prongs move backward, they cause a decrease in air pressure near them. This decrease is known as a "rarefaction." When these alternate increases and decreases are transmitted from one molecule of air to another a sound wave is set up, which radiates in concentric rings from the initial sound source. These individual molecules merely move back and forth in a neutral position, the pressure wave being the object in motion from sound source to the ear of the hearer. The number of cyclic vibrations that occur each second are known as the frequency of the sound and are expressed as cycles per second (cps) or Hertz (Hz).

Multiple Sound Waves

Complex sound waves are formed when a sound source vibrates by issuing an instantaneous series of varied basic sounds, each carrying a separate loudness and frequency. Multiple sounds are found to be composed of a single fundamental frequency and a set of harmonic overtones. The sound of the lowest frequency is known as the fundamental frequency, and the harmonic frequencies are multiples of the fundamental frequency. A second harmonic has a frequency two times the fundamental frequency, while a fourth harmonic has a frequency four times the frequency of the fundamental. Rarely is a sound composed of a single frequency—more likely to be encountered is sound comprised of a wide variety of harmonics. These harmonic frequencies are what makes it possible to hear the difference between several musical instruments, while each is playing a note on the same frequency. Voice frequencies are easily recognized by the presence of harmonic frequencies in the speaker's voice. In Figure 2-1 are shown two multiple waveforms taken from the screen of an oscilloscope. One is a noise figure and the other, a musical note. In the note will be seen a regularity of change, with components that occur again and again, while in the noise pattern no such consistent repetition occurs. In the spoken language which we employ, all the letters have separate and consistent waveforms. This is shown on the oscilloscope tracings in Figure 2-2.



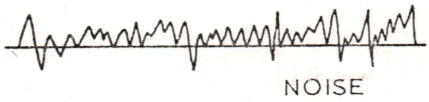
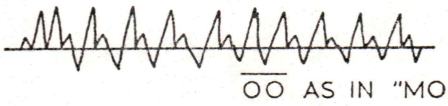


Figure. 2-1. Multiple waveforms.



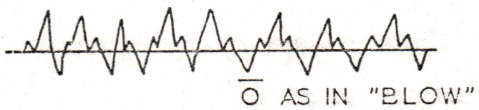


Figure 2.2 Audio waveforms.

Quality and Tone

Voice and musical sound are traditionally and accurately described in terms of amplitude, pitch and quality. Amplitude, or variation in the height of the waveform, is a way of measuring the force of a sound wave. Intensity or loudness of a sound is regulated by the amplitude. Loudness diminishes, varying inversely as the square of the distance, as we are separated from its sound source. The number of vibrations in each second, known as the frequency, is what regulates what we term "pitch" of a sound. High-pitched sounds are those of high frequency, while low-frequency sounds are of low pitch. A tone whose frequency is

twice that of another tone is said to be an octave above the basic tone. If a tone has a frequency of 440 Hz, the octave above it has a tone with a frequency of 880 Hz. Sounds differ in quality or timbre, based on the number of harmonics existing in a multiple sound and their individual sound energies. What the ear hears, therefore, is a combining of the fundamental frequency and the overtone or harmonic. It is the number and intensity of overtones existing in a given tone that determine its quality.

Speed of Sound

All tones of various pitches travel at the same speed through the air. They are transmitted at a speed of about 1,130 feet per second in air at 20° C. Since light waves have a velocity of 186,000 miles per second, the explanation of the reason that a distant object is seen before it is heard is obvious. An example of this effect is a lightning bolt whose flash is seen several seconds before the crash is heard by the ear.

Power and Frequency

In normal conversational level, the human voice carries fundamental frequencies between 100 and 300 Hz, and a total range of 100 to 5,000 Hz, including the harmonics. The fundamental frequencies of musical instruments range from 16 to 4,000 Hz, while their overtones range over 15,000 Hz. With regard to power in speech, it has been observed that the average power is about 10 microwatts (μW), the figure increasing to about 2,000 μW on vowel sounds. Devices designed to reproduce sound on the order of 200 to 2,700 Hz afford a high degree of intelligibility in the voice range. It is in this area that we are primarily interested since our investigations of voice sounds in audio, radio and telephony utilize this range.

Sound Wave Reflection

As a sound wave falls on a hard surface such as a wall or a floor, it is reflected and echoes are heard. Distinct reflections may not be heard unless the sound source is more than 56½ feet from the reflecting surface. This is due to the fact that sound sensation persists in the mind for about 1/10 of a second after the sound has stopped. For the mind to "hear" a reflected echo, it

must not bounce back to the ear before the original sound "image" is dispersed. To produce a true echo, the sound source must be at least 56½ feet away from the reflecting surface because sound waves at room temperature travel approximately 113 feet in 1/10 of a second. Reflectors are used in many cases to cause sound to be directed in a desired manner. Curved reflectors, in the form of parabolas, have been used to detect the sound of enemy aircraft and to direct the speech of public speakers in banquet halls. One type of investigative sound pickup (the parabolic microphone—discussed later in the chapter) is based on this principle.

Reverberation

In a room of considerable size, sounds are bounced back and forth time after time, being reflected from the walls, floor and ceiling. This phenomenon is termed "reverberation" and can result in improving the acoustic room qualities. Many times, however, reverberation is excessive and causes a confused jumble of words to strike the ears of the hearer. This is of great concern to the public address system operator and of even greater concern to investigative sound technicians. Covering the walls with soft drapery material will often "kill" reverberation for public address purposes, but the investigator is usually limited to attempting to place his microphones in more strategic locations.

SOUND SYSTEMS

Sound systems, from the standpoint of the investigative sound technician, may be said to be composed of a microphone, an amplifier and a reproducer. Figure 2-3 illustrates in block form the basic sound system.

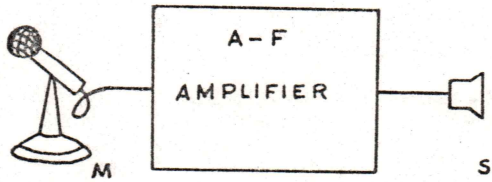


Figure 2-3. Typical sound amplification system.

The Microphone

The microphone is a device capable of converting sound waves into electrical energy. It serves to pick up the vibrations from the air by a thin metal diaphragm stretched across its surface. Microphones may convert sound to electrical energy by movement of carbon granules, by the piezoelectric effect, by movement of a coil or by change in capacitance. For convenience sake, and since many public address and common recording microphones are of the crystal type, the piezoelectric effect will be discussed. The property of piezoelectricity is the ability of a crystalline substance to transform mechanical strain into an electrical charge and for the reverse to be able to occur. Cutting a quartz crystal into a small piece and placing it between two conducting terminals will result in the production of electrical energy if the crystal is twisted. In the case of a crystal microphone, the thin metal diaphragm obstructs the sound waves and by bearing against the crystal causes piezoelectricity to flow into the circuit in which it is connected, corresponding to the a-f it has picked up. The reverse effect is utilized in headsets, wherein electrical frequencies are fed to the two conducting terminals from an audio amplifier and cause a strain or twisting action on the crystal. This strain movement is transmitted to the diaphragm in correspondence to the audio frequencies, thus converting electrical energy to mechanical vibration. This same principle is employed in phonograph pickups and contact microphones.

The Amplifier

Next in the sound system we require a device to magnify the small voltages to the input, or grid-cathode path, produced by the sounds striking the diaphragm of the microphone. The work of the amplifier is to build up the energy of a very small electric current to the point where the audio modulation on the microphone current becomes useful in level. For an amplifier to deal with audio frequencies it must meet several requirements: (1) The amplifier must magnify sound in correct proportion, whether the input voltage is of low or high level. (2) The overall amplification level must compensate for the loss of energy between the

microphone and the reproducer. (3) The amplifier must treat all frequencies equally with regard to transmission quality.

Vacuum Tube Amplifiers

There exist four general types of vacuum tube amplifiers, according to the part of the grid-plate characteristic used and the magnitude of the applied signal voltage:

Class A: The plate current flows constantly, the grid is generally not driven with positive voltage, and the plate current duplicates the input signal. This amplifier has both low efficiency and low output. (See Figure 2-4.)

Class B: The grid is biased just short of the plate current cutoff which current only flows significantly when the grid is on the input voltage half-cycle. While in this half-cycle phase, the efficient amplifier will show plate current precisely reflecting the grid input.

Class C.: The grid is biased so that no plate current flows when grid-signals are not present and only flows when the grid is charged positively during a phase of the half-cycle. High efficiency and high output mark this type of amplifier but the audio distortion level is so high that its use is contraindicated in audio circuits. Class C operation is largely limited to the radio frequencies.

Class AB: A compromise between the high efficiency of Class B type operation and the faithfulness of Class A type amplifiers is obtained by biasing the circuit so that it operates part way between these types. (Refer to Figure 2-5.)

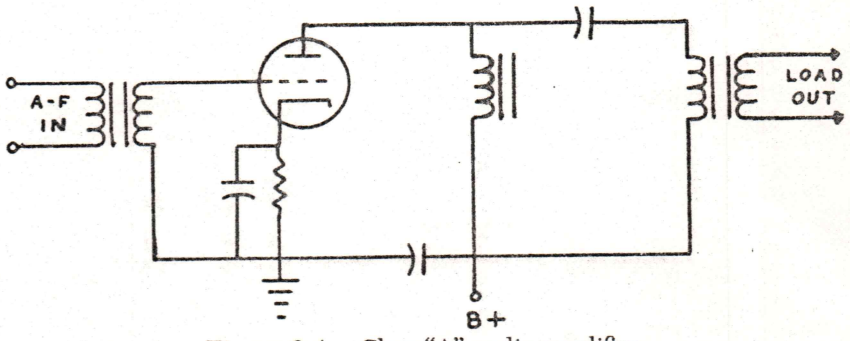


Figure 2-4. Class "A" audio amplifier.

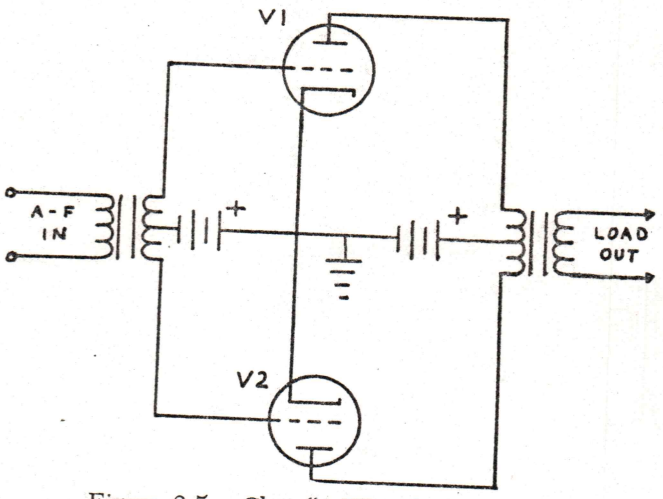


Figure 2-5. Class "A-B" audio amplifier.

1. *Resistance-Coupled Amplifiers.* Uniform amplification over a wide frequency range characterizes the resistance-coupled amplifier. (See Figure 2-6.) It is commonly used in voltage-amplifier circuits where it is found to be inexpensive and has good frequency response. Hum pickup from stray fields is minimized. This type of amplifier is the only one that should be used with the pentode output circuits and high-mμ triodes. It has been found that transformer-coupling gives too much frequency distortion when too high a load impedance is employed.

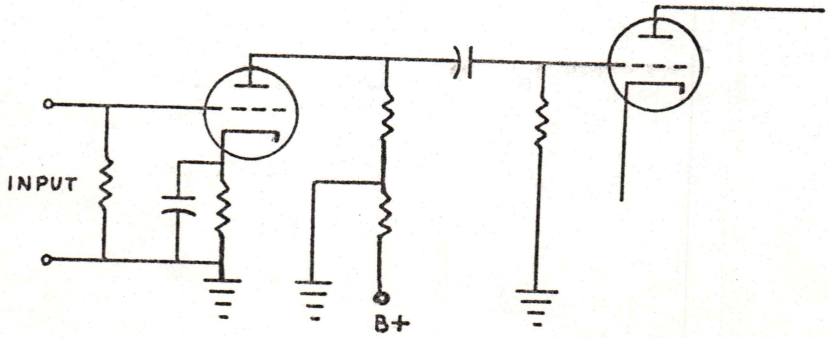


Figure 2-6. Resistance-coupled amplifier.

2. *Transformer-Coupled Amplifiers.* Maximum voltage amplification and power output can be secured with the transformer-coupled amplifier. (See Figure 2-7.) It is especially useful when the impedance or load resistance is different from the tube resistance. In addition, it is not necessary to employ high plate supply voltages. Well-designed transformers with low ratio of turns, employing high-permeability iron cores, are made to perform with flat characteristics between 30 and 15,000 Hz.

3. *Power Amplifiers.* We speak of the power amplifier as the final tube, or stage, in the amplifier that directs audio frequencies into the reproducer. Its work is not to generate a high degree of voltage multiplication but rather to transmit smooth power to the loudspeaker. All the other stages of the amplifier contribute to the magnifying of the tiny grid voltages impressed on the system by the microphone. These small voltages are built up so that they are large enough to excite the power tube grid. This final stage contains considerable power on its plate. Its job is to carry power and its grid must be stimulated with sufficient signal voltage to enable the plate variations, under load, to deliver this high power. The final stage may consist of a moderately low-mμ triode or a high-mμ pentode. The triode produces a cleaner signal but requires more grid voltage, and there is greater chance of picking up hum. Generally, two tubes are employed in a push-pull power amplifier circuit.

4. *Push-Pull Amplifiers.* In high-efficiency or high-fidelity

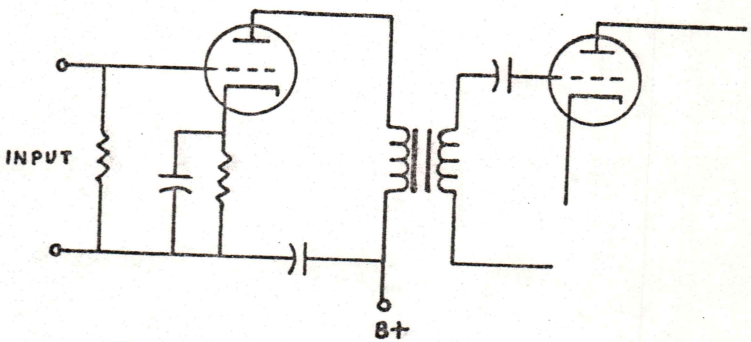


Figure 2-7. Transformer-coupled amplifier.

audio systems, the amplifier often employs what is known as a push-pull output circuit. (Refer to Figure 2-8.) The advantages of such an arrangement are many. Distortion is reduced to a figure below that which occurs when only a single tube is used, and the power output is doubled. Less filtering of the plate current is required because no stray voltage exist in the output, and regeneration of certain signal currents is not the problem it is with other types. A push-pull amplifier circuit consists of two tubes of the same characteristics and a center-tapped input transformer and audio choke.

SOUND-LEVEL MEASUREMENT. To accord some kind of meaningful order in the comparison of sound-level outputs, a measure called the bel was adopted in 1928. It was named after the inventor of the telephone, Alexander Graham Bell. In common use is the decibel (dB) which consists of 10 bels. As a unit of gain, the decibel is a logarithmic function which we believe represents the gain advancement of the human ear. Each time the power is doubled 3 dB are added to its gain. Decibels are a convenient way to express voltage gain, since they can be added instead of multiplied. It should be realized that the ear can barely distinguish a 3-dB gain (twice the power) in most amplifiers. A mathematical description of the decibel is ten times the common logarithm of the ratio of two powers. Thus,

$$N_{DB} = 10 \log_{10} (P_1/P_2)$$

where N = number of decibels by which the two powers (P_1 and P_2) differ.

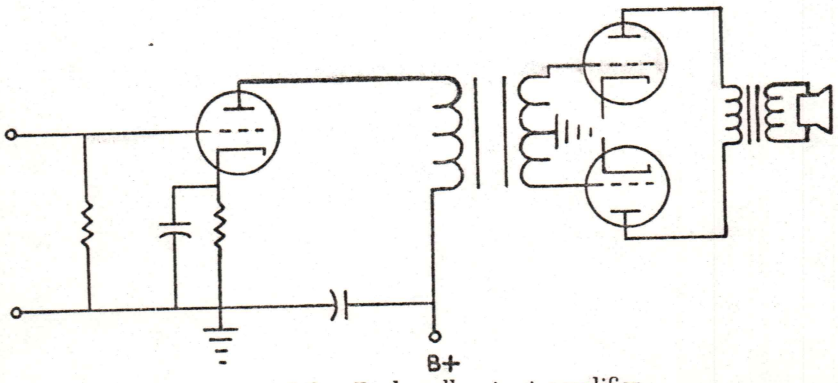


Figure 2-8. Push-pull output amplifier.

In Table IV is a listing of dB values in relation to their power and voltage values:

TABLE IV

N dB	*Power Ratio*	*Voltage Ratio*
3	2	1.4
6	4	2.0
9	8	2.8
10	10	3.2
20	100	10.0
30	1000	31.6

Level of Power. The decibel system is commonly used to state the signal output level by audio technicians who compare it with a mutually understood, fixed level. From the standpoint of music programming, a concert orchestra ordinarily covers a range of from −40 to +20 dB. This range of 60 dB has to be compressed to the approximate range of 27 dB in order to be broadcast. The zero-level in broadcast circuits is standardized as 1 mW into the standard 600-ohm line.

Equalization. The process of equalization deals with adjusting the curve of the frequency response of the audio system. Controls are available, in high-quality preamplifiers, to achieve just about any wanted curve. If it is determined that the amplifier begins to "sing" at particular frequencies, a variable loss may be inserted at that special frequency. This produces a flatter curve than if no equalization was employed. Telephone engineers have spent considerable time and energy in developing special equalization circuits to cope with unique telephone line characteristics. These equalization networks consist of variable combinations of capacitors, inductors and resistors. Such a network placed in the circuit in order to equalize transmission losses at various frequencies is known as an equalizer.

Attenuation Circuits. When it is desirable to limit the response of a telephone line or audio system amplifier to certain upper or lower frequencies, filter circuits are used to attenuate (refuse) those frequencies which interrupt voice or music frequencies which it is desired to record. These circuits consist of tuned circuits which serve as band-pass or rejection filters. They are composed of capacitors and inductors, usually of the recurrent type where they are connected in series. Uses for these circuits

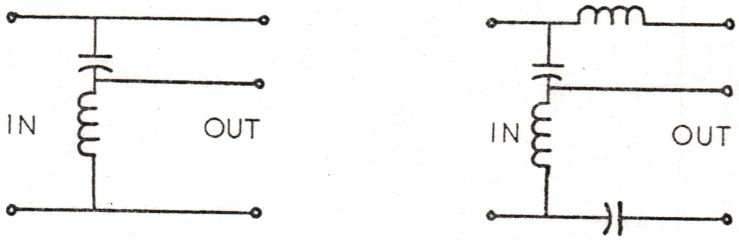


Figure 2-9. Basic filter networks.

would include such cases as when motor vehicle noise, music or any other unwanted sound frequencies were found to be interfering with the making of a voice recording. (See Figure 2-9.)

PADDING NETWORKS In order to limit voltages applied to an amplifier, while still maintaining the original frequency relationship, padding networks must be employed. These devices should have no frequency characteristics of their own, in order to not interfere with the program material. (Refer to Figure 2-10 for

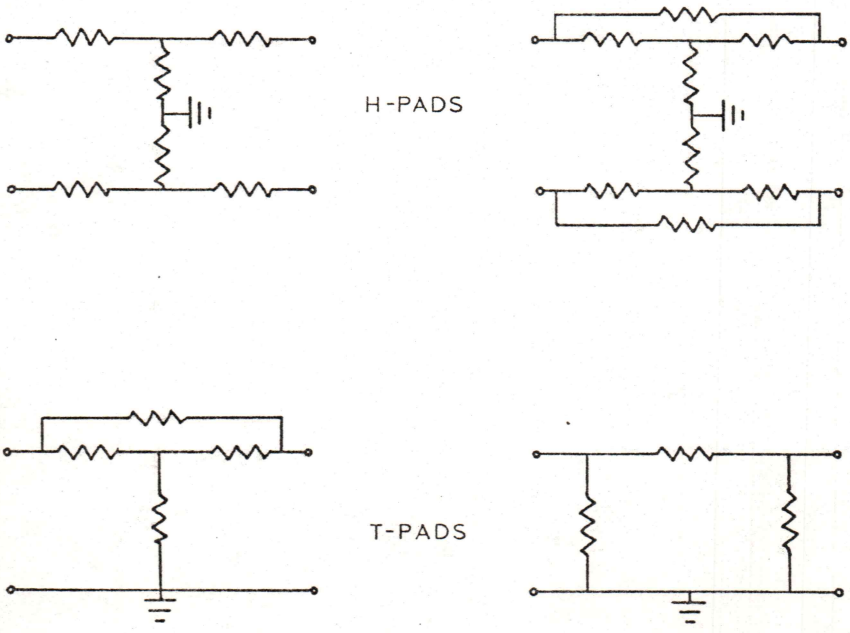


Figure 2-10. Resistance padding networks.

two basic designs.) These pads may be either fixed or variable losses. Pad networks are used when it is necessary to control the output of a sound pickup or an amplifier while still maintaining the same frequency characteristics and impedance ratios in the circuit. Some circuits must employ the H-type network in order to balance both sides of the line with ground. It can be observed that the H-pad employs equal resistances in series and a shunt resistance to ground at the center, while the T-pad is employed where a slightly unbalanced line can be tolerated.

Transistorized Audio Amplifiers

Transistor audio-amplifiers are employed in sound recorders, public address systems, sound reproducers and radio and video equipment. For audio uses, frequencies of the signals amplified encompass the range from 10 to 20,000 Hz. The transistor amplifier's input circuit usually draws current from the previous stage or directly from the input device. From this standpoint the transistor amplifier is regarded as either a current or as a power amplifier performing at a power level or current level greater than the previous stage and less than the following stage. Power levels developed by preamplifiers are ordinarily measured in micromicrowatts ($\mu\mu$W) or microwatts (μW), while driver stages are generally operated at power levels developed in hundreds of milliwatts or watts (W). These statements regarding power levels are only approximations, of course. The particular equipment in which these stages are employed regulate the power levels of the appropriate preamplifier, the driver or the power stage.

Amplifier Classification. Similar to the employment of electron tube amplifiers, transistor amplifiers may be operated Class A, Class B, Class AB or Class C at reduced power efficiency. In addition, with heavy collector current the forward current transfer ratio is significantly reduced. To avoid severe signal distortion, class B amplifiers should be operated in push-pull.

Class A: Class A amplifiers function with the transistor's collector current flowing continuously during the complete electrical cycle, though no signal may be present; this is permitted by the base bias and alternating signal.

Class B: Class B amplifiers are base-biased to the approximate collector current cut-off so that the collector current is almost zero in a no-signal state. When an alternating signal is applied to a specific transistor, the collector current flows for approximately half of each cycle.

Class AB: Class AB amplifiers may be biased so that either the collector current or the collector voltage is zero for less than the half-cycle of the signal input. The remarks above applying to the Class B amplifier may also be applied to the Class AB amplifier.

Class C: Class C amplifiers may be biased so that either the collector current or the collector voltage is zero for over the half-cycle of the signal input. In single-ended or push-pull application the Class C amplifier is not suitable for use as an audio amplifier because it produces severe distortion of the signal.

PREAMPLIFIERS. Preamplifiers are characteristically low-level stages, often following low-level output transducers such as hearing aid pick-up devices, microphones and recorder-reproducer heads. Probably the most significant characteristics of preamplifiers are the signal-to-noise level ratios, the input and output impedances, and the frequency response capability, measured in Hertz (Hz).

NOISE FACTOR. The quality of an amplifier with regard to noise is characterized by its noise factor. In determining the noise factor, calculations are made by measuring the ratio of signal-to-noise power at the amplifier's input and the ratio of signal-to-noise power at the amplifier's output. The noise factor (NF) is equivalent to the input signal-to-noise ratio divided by the output signal-to-noise ratio. Formula is thus

$$NF = \frac{S_i/N_i}{S_o/N_o}$$

The lower the signal-to-noise ratio (S/N), the better the noise quality of the amplifier. The noise factor of a particular amplifier with a certain transistor is determined primarily by the operating point, the signal source resistance and the frequency of the amplified signal.

OPERATING POINT. The operating point of a transistor is

determined by the zero-base or emitter current and the voltage. The effect of various values of emitter current on collector voltage on the noise factor of a type transistor amplifier is available in standard curves. The curves show that for a type transistor, a low noise factor may be gained by operating the transistor at an emitter current lower than 1 ma, with a collector voltage of less than 2 volts. Increasing the collector voltage raises the noise factor more rapidly than increasing the emitter current.

Resistance of Signal Source. Another characteristic affecting the noise factor of an amplifier is the resistance of the source feed transistor. The noise factor for a type transistor may be lowered by employment of a signal source resistance in the range of 100 through 3,000 ohms.

Frequency of Signal. As the frequency of the signal is increased, the noise factor of the transistor increases. It may be observed that at low audio frequencies the noise factor is high. With the increase in frequency, the noise factor becomes more tolerable to approximately 50 kHz and then begins to slowly increase. One problem in the production of audio amplifiers is the incorporation of low-noise characteristic in their design.

Resistance of Input. If a preamplifier is designed to be operated from a low-resistance signal source, the common base configuration or the common emitter configuration may be employed. The input impedance of the common base configuration is ordinarily between 30 and 150 ohms while the common emitter configuration possesses an input impedance between 500 and 1,500 ohms. A high-resistance signal source is less desirable in preamplifiers because of the large noise factor, although it is sometimes necessary to employ such a device if a crystal pickup is used. In this case a high-input resistance preamplifier would also be needed. The required high-input resistance may be gained through the use of one of three standard circuits without the use of a transformer. These are the common collector, the common emitter with series input resistance and the degenerated negative-feedback common emitter design.

Direct-Coupled Preamplifier, Two-Stage, Compensated for Low Frequency. Characteristically, to compensate for poor low-frequency output of a microphone transducer, a two-stage

direct-coupled preamplifier is employed. Through use of direct coupling, transistor Q_1's output is tied directly to the input of transistor Q_2 avoiding the use of a coupling capacitor. The reason for this is that the coupling capacitor would attenuate the low frequencies in the circuit. Through the use of a resistance-capacitance (R-C) network there is formed a low-pass filter where the higher frequencies are partially shunted to ground. In many cases, transistor Q_2 is employed in a degenerated, common emitter stage. A very high-input impedance, approximately 30,000 ohms, is gained by employment of a resistor for negative feedback in the degenerated stage. Since a very high-input impedance is employed, a relatively low-value capacitance (0.2μfd) will serve to ground the high frequencies. To reduce the noise factor both the collector voltage and the emitter current of transistor Q_1 are kept low. Since the signal is amplified by the first stage, the emitter current and the collector voltage of the second stage may be increased significantly without consequently increasing the noise factor. A common arrangement employs the coupling of the output of the microphone at the base of transistor Q_1 through the use of a transformer. The signal is amplified by transistor Q_1 with a resistance serving as the emitter swamping resistor. The a-c signal is bypassed around the swamping resistor by the use of a capacitance. The output signal is developed by a collector load resistor. Another resistance-capacitance combination forms a low-pass filter for the circuit. The signal is then further amplified by transistor Q_2, with another resistor providing negative feedback in the circuit. Again, another resistance is employed as the emitter swamping resistor. The a-c signal is bypassed around the swamping resistor by a capacitor in the final emitter circuit. The output signal is, consequently, developed by a load resistor in the collector circuit.

THREE-STAGE RESISTANCE-CAPACITANCE COUPLED PREAMPLIFIER WITH LOW-FREQUENCY COMPENSATION. Because of the poor low-frequency output of many transducers a three-stage resistance-capacitance coupled preamplifier with low-frequency compensation is often employed. This is managed by the use of two low-pass, high-frequency attenuating networks. The first R-C

network shunts the input of transistor Q_2 while the second R-C network shunts transistor Q_3's input. Transistors Q_2 and Q_3 are often employed in the common emitter circuit wherein the input of each is generally 20,000 ohms. Due to the low-input impedance, each low-pass network must employ large capacitances, on the order of 1μfd or 2μfd, and low resistance, on the order of 300 to 500 ohms, to shunt part of the high frequencies around the low-input impedance of the separate stages.

Two-Stage Resistance-Capacitance Coupled Preamplifier With High-Frequency Compensation. Common configuration two-stage preamplifiers have been designed to compensate for reduced high-frequency response of an input transducer. This is accomplished by the use of an equalizer network which attenuates the low frequencies more than the high frequencies are attenuated. The coupling transducer between transistor Q_1 and the R-C network serve mainly as a d-c blocking capacitor which attenuates the lower frequencies more readily than the higher frequencies. The resulting higher reactance at the lower frequencies results in the capacitance in the network bypassing the high frequencies around the resistance of the network, thereby resulting in maximum amplification of the higher frequencies. The network capacitor may be considered an open circuit at low frequencies, the low frequencies then being passed through the network resistance and therefore being attenuated. The relative values of the network's capacitance and resistance determines the amount of attenuation of the low frequencies. In this two-stage R-C coupled preamplifier the base resistance of transistor Q_1 determines the base-emitter bias, while the collector load resistor develops the output signal of transistor Q_1. The network coupling capacitor along with the capacitance and resistance in the network form the equalizing network mentioned above. The base resistance in transistor Q_2 determines its base-emitter bias, while the collector load resistance regulates the output signal. In some cases coupling networks between stages employ variable resistors as volume and tone controls. Signal coupling between one transistor stage and another may be accomplished with R-C networks, impedance-coupling networks, transformers and direct coupling.

The voltage, current and power gains of the stages are generally varied by using variable resistances in the coupling networks. Generally, the variable resistor is termed a "gain control." Specifically at audio frequencies the gain control is often termed a "volume control."

RESISTANCE-CAPACITANCE COUPLED AMPLIFIERS. Extensively employed with junction transistors, R-C coupling results in economy of circuit parts, high gain and small size of the equipment. Good temperature stability may be developed by the use of self-bias and emitter swamping resistors. Low-level, low-noise preamplifiers employ R-C coupling extensively in audio circuits and may be seen in high-level amplifiers for power stages as well. Battery-operated equipment often employs R-C coupling in low power operation for the purpose of limiting battery drain.

TRANSFORMER-COUPLED AMPLIFIERS. Interstage coupling by means of a transformer is often employed, due to the gain and the very low resistance in the base path, which enhances temperature stabilization of the d-c operating point. Since no collector load resistor is used to dissipate power, the efficiency of the transformer-coupled amplifier is close to the theoretical maximum of 50 percent. The transformer-coupled amplifier is found in many pieces of equipment using battery power. Another advantage in the use of transformer coupling is the possibility of maximum available power gain in a particular stage due to the matching of the load to the output of the transistor and of the source to the input of the transistor. A problem arising in the use of transformer-coupled stages is that the available frequency-response is not as good as that of the R-C coupled stage. This is caused by the shunt reactance of the primary winding at low frequencies causing the low-frequency-response to fall off. The response is also reduced at high frequencies by the capacitance of the collector and the leakage reactance between the primary and secondary windings. Another problem arises in that transformers are much more expensive, larger in size and heavier. Generally, transformers are employed in those applications which require high-output power and high-power efficiency with less regard for size, weight and battery consumption.

IMPEDANCE-COUPLED AMPLIFIERS The impedance-coupled amplifier employs one or both resistors of an R-C coupled amplifier being replaced by an inductor. In some circuits the collector load resistor is replaced by an inductor. Higher power efficiency is gained since the d-c power loss is eliminated. In the impedance-coupled amplifier low frequency-response is reduced by the shunt reactance of the inductor. Likewise, the frequency-response is reduced by the collector capacitance. This impedance-coupled amplifier does not suffer the loss of high frequencies by leakage reactance as does the transformer-coupled amplifier. The result in this case is that the frequency-response of the impedance-coupled amplifier is significantly better than the transformer-coupled amplifier while not attaining the response of the R-C amplifier.

DIRECT-COUPLED AMPLIFIERS. Direct-coupled amplifiers are most often used for amplification of d-c signals and for the amplification of very low frequencies. One of the advantages in the use of the direct-coupled amplifier is a significant decrease in circuit parts, resulting in maximum economy of the circuit. Due to circuit characteristics however, the number of stages that can be directly coupled is limited. Any temperature variation of the bias current in any stage is amplified by all of the stages, resulting in this type of circuit being characterized by severe temperature instability.

VOLUME CONTROLS. In a given circuit the volume controls must be arranged so that the volume control itself introduces a minimum amount of noise in the circuit. This characteristic is achieved by avoiding the flow of heavy d-c current directly to the volume control. A necessary characteristic of the volume control in its associated circuit is the allowance of gain from zero through maximum, and the circuit must be constructed so that all frequencies are attenuated equally for all positions of the variable control arm. Controls having an audio "taper" (curve) are generally used.

TONE CONTROLS. In addition to volume control circuits serving as current dividers, tone control circuits may be employed in this way as well. The tone control allows manual adjustment of the

frequency response of the amplifier. It is possible to arrange any low-frequency or high-frequency compensating network in the form of a tone control circuit by replacing a manually variable element of the circuit for one of the fixed circuit components. In some circuits, the substitution of a variable resistor for one of the resistances in the low-frequency R-C compensating network will result in the production of a low-frequency boost tone control circuit. In a high-frequency R-C compensating network, the substitution of a variable resistance results in a high-frequency boost tone control circuit.

Driver Stages. In equipment producing high audio output, driver stages are located immedately before the power output stage. In common practice, most output stages are push-pull stages that require two input stages, each 180 degree out-of-phase with the other. This phase requirement is provided for the push-pull stage by the use of a tapped secondary transformer between a single, and a driver, stage and the output stage. For better frequency response and purposes of economy, the transformer coupling may not be desirable and R-C coupling may be employed for better economy and for better frequency response. If R-C coupling is employed between the driver stage and the push-pull stage the driver stage must provide phase inversion to produce the two signals 180 degrees out-of-phase. Phase inverters may use one transistor stage or two stages employing two transistors.

Reproducers

Reproducers include headphones and loudspeakers, both of which convert electrical energy to sound waves. Magnetic and crystal types of headphones are in common use. Magnetic headphones function when a signal is sent through the coil of fine wire surrounding the magnetic pole-pieces, further causing magnetic fluctuations which move a thin, soft-iron diaphragm and set the opposing air in vibration. The d-c coil resistances vary, usually, between 1,000 and 2,000 ohms, and a-c magnetic impedances vary between 10,000 and 20,000 ohms at 1 kHz.

The function of crystal headphones was discussed under

microphones, earlier in this chapter, when piezoelectricity was mentioned. The quartz crystal unit is mounted to the base of the case, while the free end of the crystal is attached to a diaphragm. Impedance of these headphones is several times more than that of standard magnetic headphones. Crystal headphones are flat in response to over 10,000 Hz, while magnetic types have a maximum response between 500 and 1,000 Hz. In circuits where d-c is flowing, such as the plate output of a vacuum tube, magnetic headphones may be connected in series, while crystal headphones would be destroyed by this unless coupled by a d-c blocking condenser.

Loudspeakers most widely used are of the dynamic type, with magnetic speakers running a close second. Electrical signals are applied to a small coil, known as the voice coil, which is positioned so that it may freely move in the gap at the end of a magnet. The voice coil is mounted so that it moves only along its own axis and is attached to a large, conical fiber diaphragm. Voice coil impedances are low, due to few turns in the winding, being on the order of 3.2 to 16 ohms. The diaphragm is placed in motion by the fluctuating polarity of the current sent through the voice coil and subsequently causes the production of sound waves.

Output terminals for a variety of loudspeaker impedances are generally provided. Most often sockets are included to cover 4-, 8- and 16-ohm speakers. Occasionally, 250- and 500-ohms connections are found. These higher impedances are designed to match long lines to which the loudspeaker must be connected with a matching transformer placed close to it. A 16-ohm loudspeaker would require a line matching transformer of 16 to 500 ohms rating, provided that a 500-ohm line were used.

Loudspeakers are manufactured in hundreds of varieties and in a wide range of prices. For investigative sound requirements, only impedance matching and size of the speaker are important. If the system is intended for voice range requirements, almost any permanent magnet speaker of the proper diameter and impedance may be used. Types that are manufactured for replacement purpose and sold through radio parts wholesalers do

very well for this service. If it is desired to make provision for the reproduction of music frequencies with any degree of fidelity, it is recommended that the technician obtain a good text on high-fidelity music systems in order to study the requirements of the various special loudspeakers and enclosure designs. Such a treatment is definitely outside the scope of this work.

Headsets

Of particular interest to the investigative sound technician is the wide variety of headsets available and necessary in his work. Headsets may be of magnetic, crystal or dynamic type and are manufactured in many styles and impedances.

For general use, a good pair of magnetic headphones equipped with a covered spring-headband and ear cushions are recommended. They should be furnished with a double headset cord of rugged design, to which is attached a screw-terminal headphone plug. Use of the screw-terminal plug permits the headphone tips to be easily removed from the plug for use in testing circuits. The author uses several pairs of army surplus HS-33 low-impedance headphones, which are extremely well-made and which are equipped with a sturdy leather-covered headband. Lightweight headsets and earsets are produced by Telex and are available in a variety of impedances. Some of the Japanese crystal earsets can be utilized to advantage in miniaturized investigative devices. For headphones of greater frequency response the technician will choose crystal or dynamic sets. Brush makes a good line of high-fidelity crystal headsets with frequency response to 10,000 Hz. Dynamic headsets, also known as moving-coil headphones, are considered to be professional-type, broadcast quality headsets. They consist essentially of two miniature high-fidelity loudspeakers, exhibiting wide tonal range and distortion-free reproduction. Sets are available with either rubber, liquid-filled, or chamois ear cushions. Koss and Superex, in the United States and British Industries in Great Britain produce exceptionally fine units.

Portable Battery-Operated Units

Hearing aid units employ a type of preamplifier powered by

batteries and designed with low-drain tubes or transistors. They are small in size and operate efficiently at voice frequencies. The Centralab, Ampec audio amplifier, PC-201, is an older sub-miniature unit employing a CR 548-DX and two CK 512-AX tubes. The unit is a three-stage amplifier, operating on a 22½ volt "B" supply and a 1.5 volt "A" supply. It has a gain of 4,500 at 1,000 Hz, and its response is 200 to 3,000 Hz. Its size is smaller than a book of matches.

Centralab produces a packaged transitor amplifier which has much usefulness for the sound technician. It is the Model TA-11 which is as small as an airmail stamp. This amplifier has a gain of 74 dB and an output of 1 mW. The input impedance is 1,000 ohms and the unit is sealed in epoxy resin to provide protection against moisture and to protect against abrasive wear. Other concerns produce a multitude of the late-type integrated circuit audio frequency amplifiers suitable for investigative applications.

Most hearing aid amplifiers can be converted to investigative applications by making provisions for input impedance matching. Figure 2-11 and Figure 2-12, respectively, illustrate schematic diagrams of the Ampec PC-201 amplifier and of a portable, battery-operated unit popular in intelligence use. Figure 2-13 illustrates the adaptation of a typical commercial hearing aid to investigative use by alteration of the input circuit for microphone and 600-ohm line input.

Line Preamplifiers

When using low-impedance microphones over long lines, it is often desirable to boost the output of the microphone to a point where low-level sounds occurring within the effective radius of the unit are transmitted intelligibly over the line. This may be accomplished by the use of single or dual stage line preamplifiers. The preamplifier may be either low-Z to low-Z, or low-Z to high-Z, depending upon which one offers the maximum usefulness. Figure 2-14 shows a type preamplifier which has been designed to match a low-Z microphone to a high-Z recorder or amplifier input. In this case the microphone is attached to the long lines, which are then connected to the preamplifier. The preamplifier

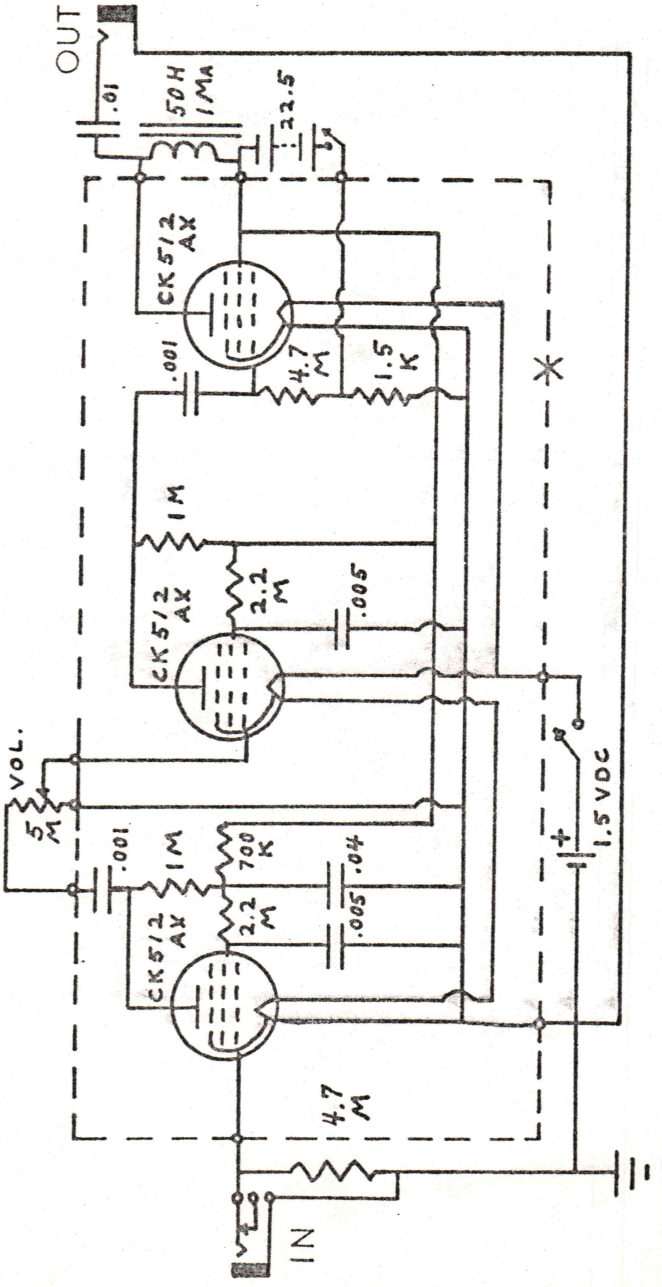


Figure 2-11. Older model miniature amplifier (tube).

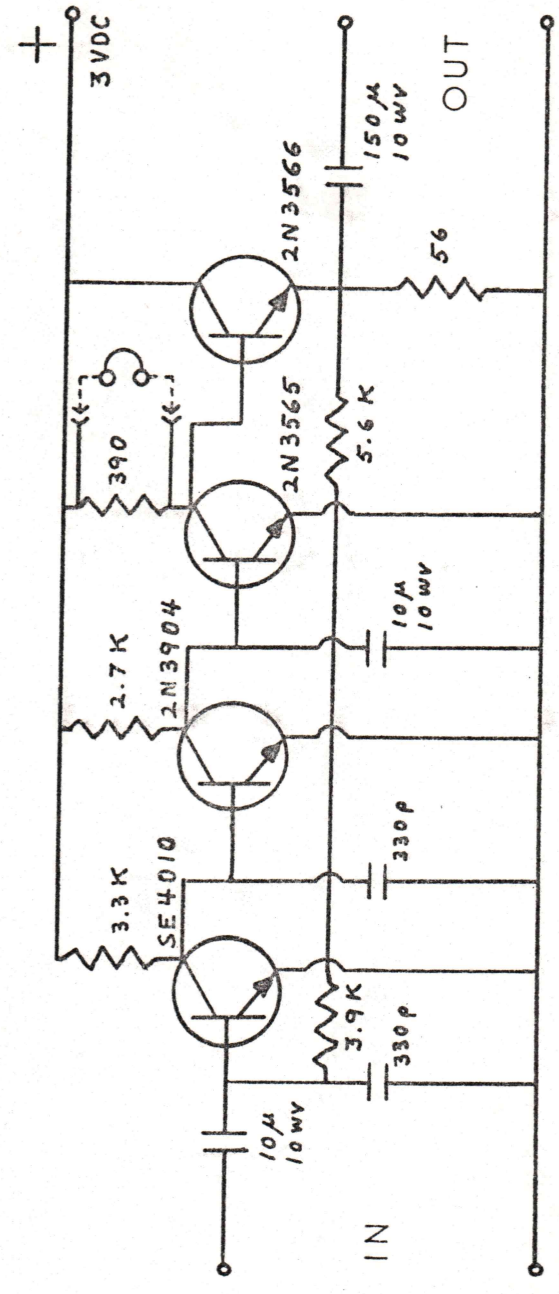


Figure 2-12. General purpose surveillance amplifier (transistor).

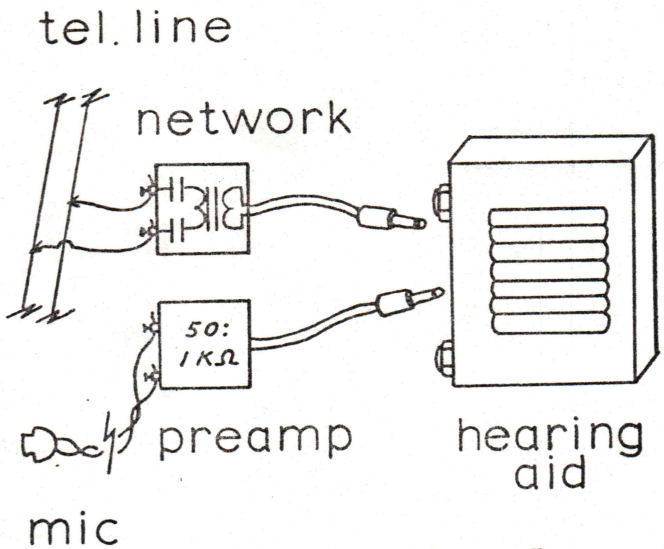


Figure 2-13. Hearing-aid adapted for surveillance use.

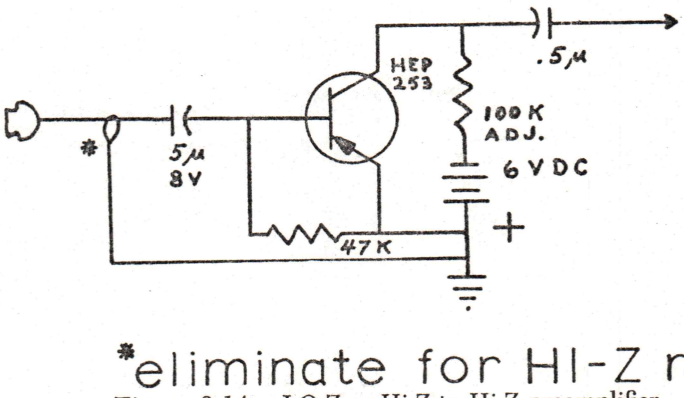


Figure 2-14. LO-Z or Hi-Z to Hi-Z preamplifier.

is then patched into the recorder or amplifier. Often, these preamplifiers are not provided with volume controls, the control taking place in the recorder or amplifier.

Special Preamplifiers for Investigative Use

Certain subminiature transistorized preamplifiers have been found to have special application in technical investigations. If

any one piece of equipment had to be selected as being the "most important" item in a physical security or technical intelligence kit, the general purpose preamplifier would be universally designated. It can be used to boost the usable output of many microphones and to match their impedance to the input of the recorder or monitor amplifier. The preamplifier can be used also for monitoring telephone lines, tracing out hidden microphones, locating clandestine transmitters, tracing out unknown telephone lines and as a metal locator, with minor variation in switching for each such employment.

It is important that a battery-operated preamplifier utilized for this purpose meet certain criteria. A list of these qualities is shown below:

1. Easily concealable in size.
2. Low battery drain.
3. Easily *replaceable* battery.
4. Easily *available* battery.
5. High gain.
6. Low-noise figure.
7. Multiple impedance input.
8. Multiple impedance output.
9. Gain control.
10. Separate function switch.
11. Sturdy, vibration-proof construction.
12. Uses rugged plugs and jacks that are available in the field and easily replaceable.

MICROPHONES AND SOUND PICKUPS

A study of voice interception methods must necessarily begin with an examination of the various types of microphones and sound pickups in use. This section outlines the several types of microphones and sound pickups, their characteristics, cabling requirements, matching transformers and optional hardware such as supports, floor stands, booms and fittings. Included is a section on microphones particularly recommended for investigative use.

Microphones are selected for service in a particular assignment dependent upon conditions encountered in that specific task. Such characteristics as application, directivity, sensitivity and response to thermal or physical shock must be considered. With regard to application, it is recommended that if music is to be recorded, dynamic or ribbon microphones be used in order to best reproduce the wide frequency response and full dynamic range of the instruments. Voice applications can be handled by crystal, ceramic, magnetic and carbon types. If the microphone is to be used outdoors, it is wise to select one with a blast filter.

Microphones exhibit a directivity pickup pattern and are further classified according to the direction in which they are sensitive. (See Figure 2-15.) Omnidirectional (also known as all-directional or nondirectional) microphones respond equally well to the sounds from 360 degrees, in a plane perpendicular to the axis of the microphone. In this way omnidirectional microphones are useful for recording groups, orchestras and meetings. If they are of small diameter, they are especially useful for hand-held or neck-suspension (lavalier use) service.

Bidirectional microphones (also known as figure-8 microprones) exhibit a particular sensitivity to sound which occurs to the front and rear, while rejecting sound from the sides. Reverberation and pickup of random noise are reduced by up to 65 percent over nondirectional microphones. This microphone permits the user to stand farther away from it, on the sensitive sides, and allows an unique freedom of motion. The bidirectional microphone is widely used in radio, television and recording studios and is frequently found in permanent speaker's stands and lecterns.

Unidirectional microphones are those which show an extreme directional characteristic. They are considered the ultimate in wide response and single directivity. Also known as cardioid pattern microphones, due to their heart-shaped pickup, they are sensitive at the front and essentially dead at the rear. Generally, the front-to-rear sensitivity ratio is 7 to 1. Acoustic feedback (howl) caused by sound from the loudspeaker reaching the microphone is avoided, and this design allows greater usable volume

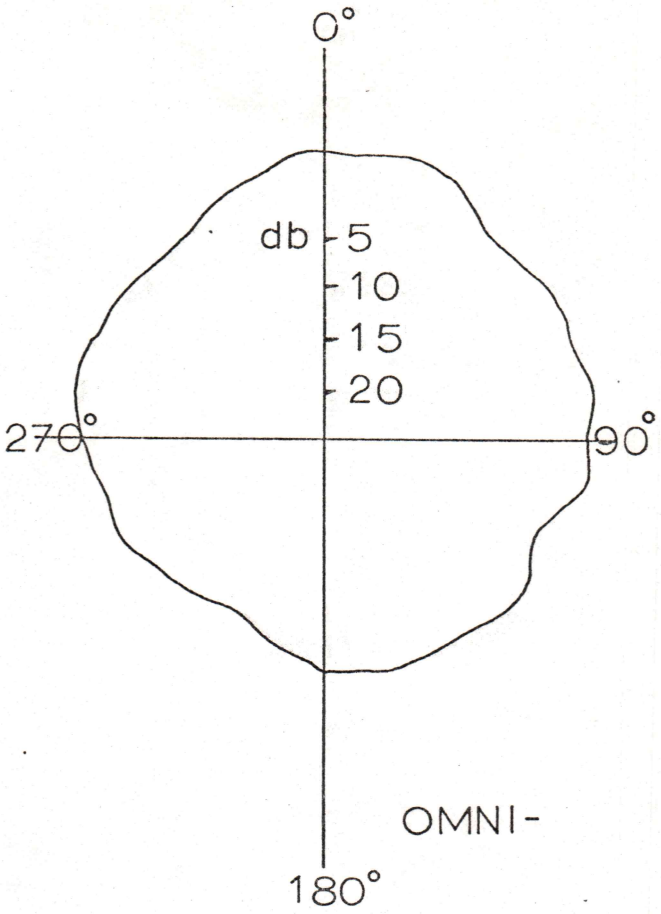


Figure 2-15. Omnidirectional microphone pattern.

with lower background noise. It also allows the PA system to be operated at higher gain settings before acoustic feedback begins than when other types of microphones are used.

Semidirectional pattern microphones have a pattern similar to that of the cardioid type. It can be observed, however, from the pickup pattern shown in Figure 2-16 that there is less rejection of sound pickup from the rear. This microphone is marked by its variable directivity. It is almost omnidirectional at low frequencies and sharply directional at the higher frequencies.

The sensitivity of the microphone is an important considera-

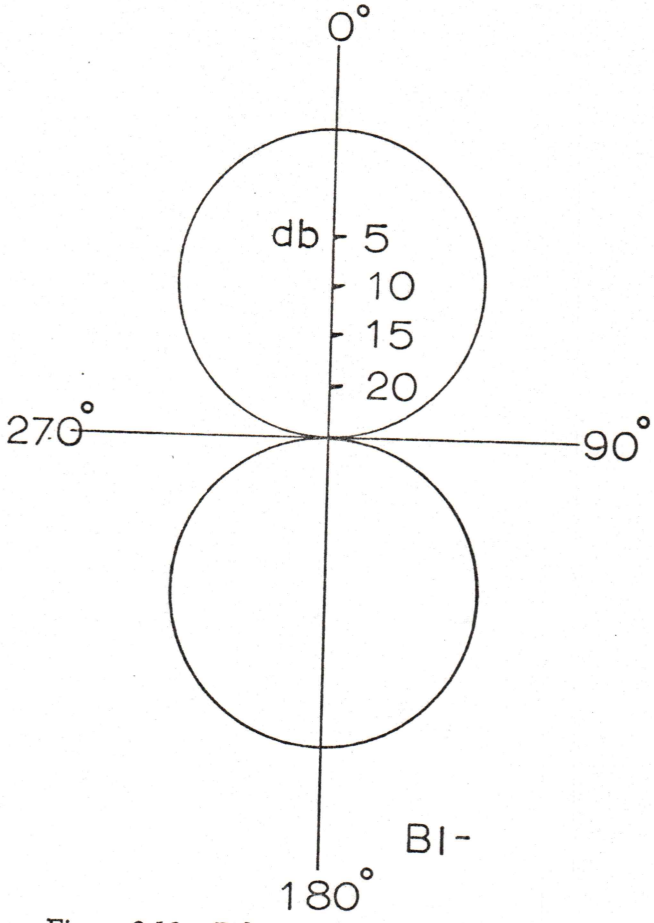


Figure 2-16. Bidirectional microphone pattern.

tion and is generally measured in negative decibel readings. This measurement, also known as output level, will vary between –45 dB and –60 dB. The lower the number, the more sensitive the microphone. For example, a microphone which exhibits an output level of –55 dB is more sensitive than a microphone which has an output level of –60 dB. Public address systems generally may be used with any type of microphone from the standpoint of output level, but microphones used with home-type recorders should be on the sensitive side of –55 dB in order to minimize hum. Professional tape recorders can handle up to –60 dB level

microphones satisfactorily. Microphones employed in investigative work are generally as sensitive as can be obtained.

Resistance to shock, both thermal and physical, is a matter of some importance in many instances. Perhaps the most rugged units are of the carbon variety, with ceramic units running a close second place. Particularly sensitive to heat are crystal microphones and sound devices. They contain a Rochelle salt crystal which is destroyed by high temperature and unusual humidity or moisture conditions. Velocity and condenser microphones are both sensitive to unusual physical shocks, and the velocity microphone may be damaged by wind blowing the internal ribbon too far.

Impedance Matching

Most sound recorders and amplifiers designed for home use, and many recorders and amplifiers of the professional variety employ high-impedance (high-Z) microphone inputs. They vary in value but are generally over 50,000 ohms. In order to efficiently utilize a microphone or sound pickup with these reproducing units, they must be electronically matched to the amplifier or recorder. This matching process involves coupling a microphone or sound pickup of a specific impedance to the impedance of the recorder or amplifier. In some cases the microphone in question will already be of high impedance and no further matching is necessary. When matching a microphone of low impedance (low-Z), however, to the high-impedance input of the recorder, line matching or microphone matching, transformers must be employed.

Generally, these line-matching transformers offer a choice of 50 to 100 ohms and 200 to 250 ohms on the primary coil and over 50,000 ohms on the secondary coil. The low-impedance sound pickup or microphone is connected to the primary side of the transformer with special cable, and the secondary side is cabled directly to the high-impedance input of the recorder or amplifier.

Some recorders and amplifiers offer low-impedance microphone inputs. These, of course, do not require matching for low-impedance microphones of moderate cable length. High-impedance microphones and sound pickups may, in emergencies,

be matched down to the low-impedance inputs, although this is not a satisfactory standard practice. If long cables are to be run between the low-impedance microphone to the line (500 to 600 ohms), further matching the recorder to the line on the other end is sometimes utilized. Two line-matching transformers are then needed—one 30 to 50 ohms to 500 to 600 ohms, and one 500 to 600 ohms to the recorder input impedance. Naturally, losses are to be expected. Signals from microphones thus matched are usually given an extra stage of preamplification at either end of the circuit. Preamplification at the microphone end with a 500 to 600 ohm output, thereby eliminating one line-matching transformer, is to be preferred.

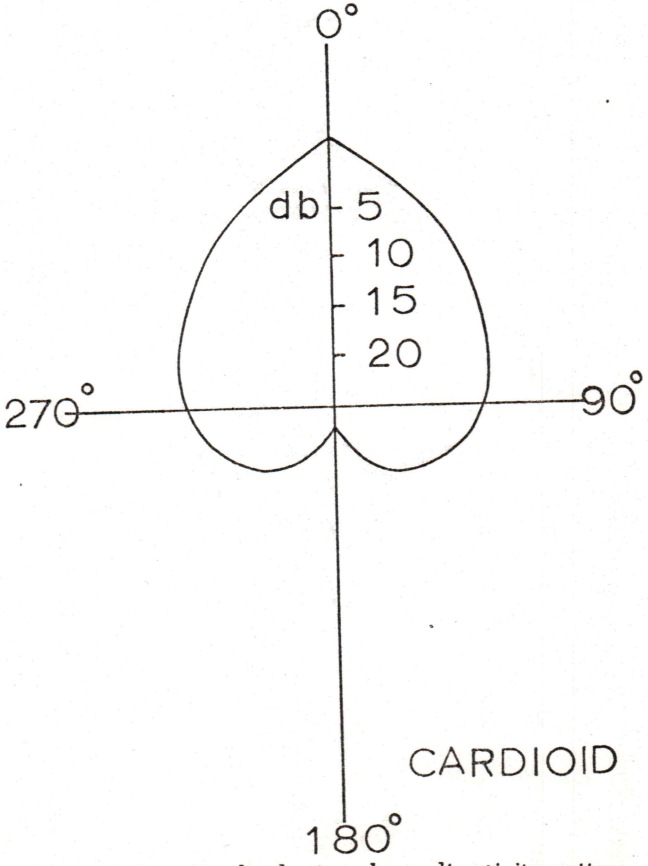


Figure 2-17. Cardioid microphone directivity pattern.

The Carbon Microphone

Carbon microphone types are the earliest microphones and have been found to be the most sensitive. They are of low impedance and long, unshielded lines may be run between microphone and amplifier. One main disadvantage is that random fluctuations in contact resistance between carbon granules results in a noticeable characteristic hiss in the circuit. The principle of operation of this microphone is that the resistance of a pile of carbon granules varies inversely as the pressure upon it. An insulated cup, placed in contact with a diaphragm, is packed with carbon granules. This cup, called a carbon button, is placed

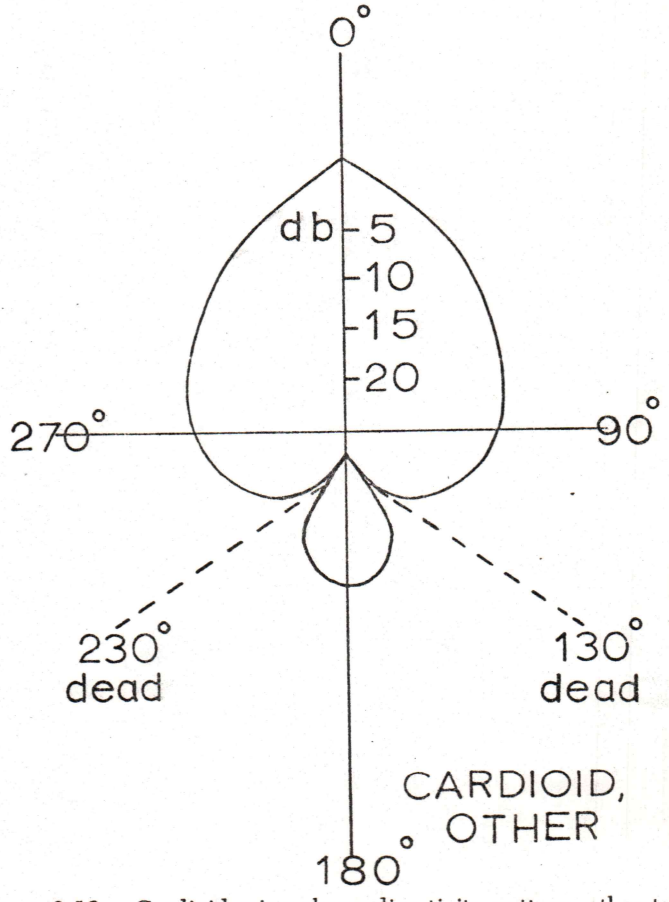


Figure 2-18. Cardioid microphone directivity pattern, other types.

against the diaphragm in such a way that any motion of the diaphragm affects the pressure on the carbon granules and thus causes variation of the resistance of the carbon button. The carbon microphone is placed in series with a battery and the primary winding of a microphone transformer. Figure 2-19

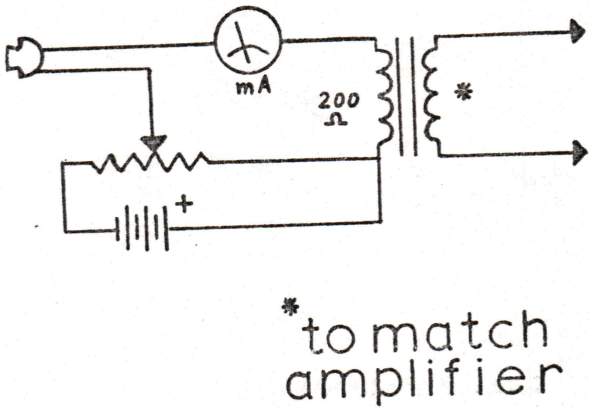


Figure 2-19. Carbon microphone input circuit.

illustrates a typical circuit matching the carbon microphone to the input of an amplifier. When no sound is received by the diaphragm, the internal resistance of the carbon button remains constant, and a consistent flow of direct current results. As sound waves cause the diaphragm to react, the diaphragm then causes pressure variations on the carbon button which results in variations in the flow of direct current in the circuit. Thus does the carbon microphone cause the d-c current flow to vary with the frequency and intensity of the sound waves it detects. The voltage on the secondary coil of the microphone transformer in this way alternates with the frequency and intensity of the original sound waves.

Carbon microphones may become "packed" in operation due to excessive pressure against the diaphragm or too much current flowing through the button. This condition causes a loss in output and decreased sensitivity and results from the carbon granules adhering to each other. A means of control is the potentiometer

seen included in the circuit in Figure 2-19. Manufacturers' ratings for current drain on carbon buttons vary between 5 and 100 ma, and the potentiometer should be adjusted so that the current drain does not exceed the manufacturer's rating. Gentle tapping frees a packed carbon button. Frequency response of carbon microphones is limited to the voice ranges and thus they are widely used in telephone and communications radio applications. The Western Electric E1 , F1 and T1 carbon microphones, used in various telephone handsets, are microphones of this type. Before the wide availability of low-cost commercial carbon microphones, telephone companies the world over lost many thousands of their telephone microphones, due to pilferage by experimenters and miscellaneous users. It is now possible to secure them from enforcement equipment suppliers (see Appendix) at reasonable cost or on the military electronic surplus market.

The carbon microphone is the only microphone that serves also as an amplifier, since its output energy is more than that which activates its diaphragm. Additional advantages are low cost, ruggedness and light weight, in addition to ease in concealment and the capability of use with long-run unshielded cable.

Since the carbon microphone is generally recognized as the most sensitive microphone made, care must be exercised in the placement of this microphone in a room for recording purposes. The supersensitive carbon microphone picks up movement noises, whispers, et cetera, and with an efficient sound recorder enables the recording of these minute sounds. It must be remembered, however, that sounds of higher intensity, such as typewriter operation, auto horns and radio-television audio systems, will be picked up at correspondingly greater efficiency levels, and "blasting" may result if the listening unit is operated at high-volume levels. As a rule of thumb, operate the unit at a volume level just loud enough to enable the recording of intelligible speech and no louder.

It is wise to recall that the human brain enables the ear to filter or discriminate sounds when one is listening to speech and unconsciously reject those sounds not part of the speech objective in order to facilitate understanding. Obviously this power of

discrimination is not possessed by microphones which record sounds of equal intensity and frequency without differentiation, except with regard to mechanical limits of cyclic range.

If sounds within the speech range occur during the recording of speech, the understanding of parts of the recorded speech may be limited. Be careful of foot scuffling, movement of furniture, rattling of sheets of paper, clearing of throats, playing of radio or television sets, and passing motor traffic. Since the super-sensitive carbon microphone is so efficient in picking up sounds, it is especially sensitive to physical vibrations. For this reason, the microphone should be cased in a rubber shock-mount and suspended from a rubber band. In the event that the microphone is not supplied in a rubber shock-mount, one may be fashioned from a sponge rubber powder puff or cellulose sponge available in any variety store. It is recommended that the microphone in use be suspended from a stationary object by a rubber band attached to the mounting clip or pinned to the shock-mount. Care should be exercised to insure that the face of the microphone is toward the source of the sound to be recorded. Be especially careful when using the microphone behind window drapes, since the window to the rear of the microphone acts as a sounding board for sounds occurring outside the room, and the microphone may pick up an amazingly accurate transcription of sounds in the street outside, while barely recording the speech sounds within the room.

Insure that the microphone installed behind window drapes does not revolve so that its face is toward the window, since the sounding board effect mentioned above will be greatly magnified. Microphones may be hidden in many places in a room (see Chap. 5). Several of these places suggest themselves, and others will be found by trial-and-error placement. The undersides of divans, chairs, and beds are generally suitable for rapid installations, although one must be careful in the placement of a microphone suspended from the springs of a bed if there is much chance that the bed will be used during the surveillance. Rhythmic spring squeaking has obscured more than one criminal investigative sound recording.

Microphones may be placed at the rear or on the undersides of tables, bureaus, cabinets or the like, if there is little chance for these objects to be moved during the course of the surveillance.

Wiring should be run from the microphone out of the room by the shortest practical route. Care must be exercised that the cables not be disturbed accidentally by sweeping, cleaning or by one of the subjects kneeling on the floor to recover some dropped object. Cables may be run through holes bored in the wall or floor and disguised with paint and putty, disguised as telephone extension or electrical extensions, or by prying away the floor or ceiling moulding and concealing the wire behind it. The carbon microphone matching unit may be purchased (see Appendix) or constructed by the technician, as is illustrated in the succeeding text. Frequency response of carbon microphones is approximately 100 to 3,000 Hz.

The Crystal Microphone (Including Ceramic Types)

Crystal microphones are sensitive and omnidirectional and have a frequency response that is essentially flat covering the audio-frequency range. They are light in weight, fairly rugged and require little maintenance. Crystal microphones, however, have several disadvantages that in some cases limit their usefulness to the investigator. They are sensitive to heat above a certain limit, *moisture can ruin a crystal microphone,* and since they are high-impedance (high-Z) units, shielded cable must be used to couple them to the amplifier. In addition, the microphone cable should not extend farther than about 18 to 25 feet between the microphone and the amplifier to prevent attenuation of the higher frequencies.

Crystal microphones employ the piezoelectric qualities of crystalline substances. It has been found that the voltage output of Rochelle salt crystal is greater than for other crystalline substances, and for this reason it is widely used for microphones. The sound cell, as it is termed, is composed of two thin crystal wafers, each bearing a sheet of metal foil on both its sides, *cemented together.* Figure 2-20 illustrates the composition of a typical *bimorph* crystal sound cell. Generally the crystal sound

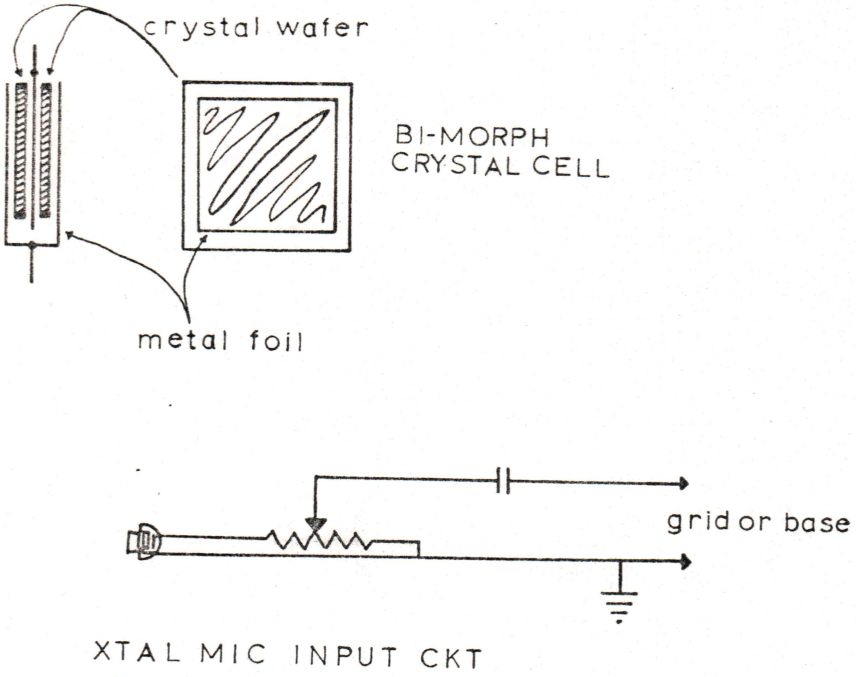


Figure 2-20. Crystal microphone and typical circuit.

cell is attached directly to the diaphragm (which transmits sound waves converted to kinetic energy) *to bear against the crystal unit.* Vibration of the crystal produces piezoelectricity in the form of an alternating voltage which essentially duplicates the original sound waves in intensity and frequency. The output of the crystal microphone is fed to the input of the amplifier without the need for applied voltage or current. Since the output of the crystal cell is quite low, several preamp stages are generally employed to boost the output to a more efficient level.

When using crystal units as sound pickups, the amplifier must employ several high-gain stages in order to enable efficient reproduction. It will be found that excessive hum in the circuit may be avoided by the use of resistance coupling between stages. This is true of most high-gain amplification circuits.

Quite characteristic of crystal-type pickups is the fact that they are often destroyed by exposure to temperatures in excess

of 125° F and by exposure to conditions of excessive moisture. Thus, carrying a crystal pickup or microphone in the trunk or glove compartment of a car on a long trip could prove disastrous. Along the same line, the installation of a crystal microphone in the dash or headliner of an automobile which could be expected to heat over the danger point might be the cause of technical failure. Be careful of installing crystal microphones in heating ducts or outdoors under conditions of rain or dew. Remember that temperatures inside heating ducts are many times that of the room they are required to heat and that a chilly subject or efficient thermostat can result in a ruined crystal unit. In such cases a dynamic microphone would be indicated. It is also possible to employ a ceramic microphone where extremes of heat and humidity are encountered. The use of such a ceramic microphone would result in only a slight loss of lower frequencies and offer the advantage of a slight boost in output. Insure that no voltage is placed on the crystal unit, since even the low voltage of an ohmmeter may ruin a crystal microphone. In the event that difficulties occur, major manufacturers supply crystal and ceramic replacement microphone cartridges at nominal cost. Frequency response available varies from about 50 to 9,000 Hz.

The Dynamic Microphone

Also known as a moving-coil microphone, the dynamic unit has wide general application in the audio and recording field. Its high sensitivity results mainly from the use of an unstretched, nonrigid diaphragm. Dynamic units are light, compact and essentially self-powered. In addition, they are quite rugged and free from the deleterious effects of temperature, humidity and shock.

One of the greatest advantages of the dynamic microphone is that it is a low-impedance (low-Z) unit, and long lines may be run between microphone and amplifier without frequency attenuation or hum (if shielded cables are employed). If desirable, high-impedance models are available. These contain a matching transformer (low-Z to high-Z) to match the low-impedance microphone to the high-impedance (100,000 ohms or so) input of the amplifier or recorder. The author employs one of the

popular Turner models, which contains a switch so that different impedances may be selected.

In operation, the dynamic microphone employs a coil of wire, attached to the rear of the diaphragm, which is flexible and free to move without friction in the strong magnetic field of a surrounding, stationary permanent magnet. When sounds impress the diaphragm, they cause the coil to go into motion, in the radial magnetic field, according to the condensations and rarefactions impressed thereon. In this way are the mechanical movements of the diaphragm converted to the currents in the coil which reproduce the intensity and frequency of the original sound. Figure 2-21 illustrates the functioning and typical circuit of a dynamic microphone. Since the dynamic microphone bears a coil in its case, one must be especially careful to keep it away from the influence of strong electrical fields when recordings are being made. Extreme hum conditions will result if a dynamic microphone is not so isolated. It is important to be especially

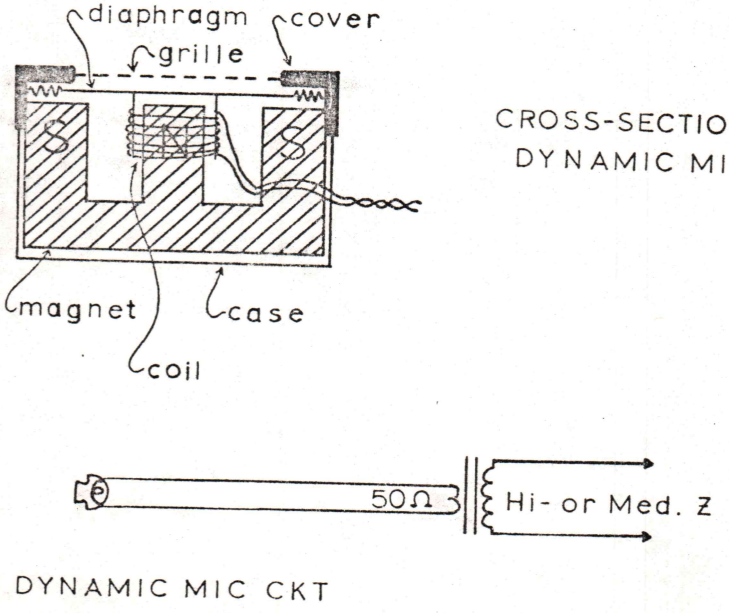


Figure 2-21. Dynamic microphone and typical circuit.

careful with in-the-wall concealment, hot water heaters with electrical switching, thermostats, airconditioners, oil burners and so forth. Frequency response available covers 40 to 15,000 Hz.

The Magnetic Microphone (Including Controlled Reluctance Type)

The principle of operation of this type of microphone is similar to that of the dynamic microphone. The main difference is that the diaphragm is attached to one end of an armature which then bears between the poles of a permanent magnet. The induced variable current results in a pair of coils mounted on the poles of the permanent magnet. The magnetic microphone, which is rugged and cheap, is sensitive enough for investigative use when employed with the preamplification that is recommended for all other types of microphones, with the exception of the carbon unit. Especially adaptable to investigative uses are the Shure MC series of subminiature controlled reluctance microphones. They have an impedance of 1,000 ohms, which is designed for matching transistorized preamplifiers and may be matched to any other type unit. The author has used them with 250 feet of twisted, unshielded pair with but little loss. Shielded cable is, however, recommended for best results. Their price, at the time of this writing is approximately $7.50, which compares exceptionally with dynamic units selling for two to three times that amount. It should be noted that microphones employed for investigative uses must sometimes, of necessity, be "throw-away" units, and department heads will appreciate the reduced costs. Frequency response is generally about 100 to 9,000 Hz. The subminiature dynamic microphones manufactured by both the Knowles and the Tibbetts companies are inexpensive and suitable.

The Velocity Microphone (Including Gradient Types)

A microphone that has been used for years in the radio broadcasting area, the velocity or ribbon microphone, has very good frequency response and requires no applied power. It is fairly rugged and may be either unidirectional or bidirectional. However, the velocity microphone is quite sensitive to winds or strong breezes and should even be protected from stray drafts.

Actually, this microphone adapts a principle of the moving coil, or dynamic, microphone in that a single thin strip of corrugated aluminum or duralumin is suspended in the magnetic field of a permanent magnet. The ribbon itself functions as diaphragm and voice coil in one. Since only this single conductor cuts across the lines of magnetic force of the magnet, this ribbon microphone is necessarily not as sensitive as the conventional dynamic type. This corrugated, metallic ribbon, which is capable of approximately ⅛ inch free movement, is actuated by the movement of the air surrounding it. The ribbon vibrates with the sound waves by which it is struck; and as the ribbon cuts the lines of magnetic force, it develops a voltage which corresponds in intensity and frequency to the sound applied. The term "velocity" results from the force applied to the ribbon, which is equal to the difference between pressures on front and rear of the ribbon. It is this resultant force which is directly proportional to the velocity of the condensations and rarefactions of the air and which suggests the naming.

Sound waves which strike the ribbon from the front, or from the rear, result in vibration. Since the ribbon is very thin, sound waves approaching from the side are ineffective in loading the ribbon. Low frequencies are accentuated at close range by velocity microphones, and for this reason, the sound source should be at least several feet away if a flat response is desired. Frequency response of velocity microphones varies, generally, from 30 to 15,000 Hz. Figure 2-22 illustrates the construction and circuit of a typical velocity microphone. All velocity microphones are low-impedance units and are matched to the amplifier input with an internal or external matching transformer.

The Condenser Microphone

Perhaps the finest of all microphones, from the standpoint of fidelity and frequency response, is the condenser, or capacitor, microphone. Its cost is generally higher than that of any other type of microphone and often begins at over $300. The condenser microphone has an extremely high-impedance output, which is seriously affected by the capacitance of the cable. Due to this

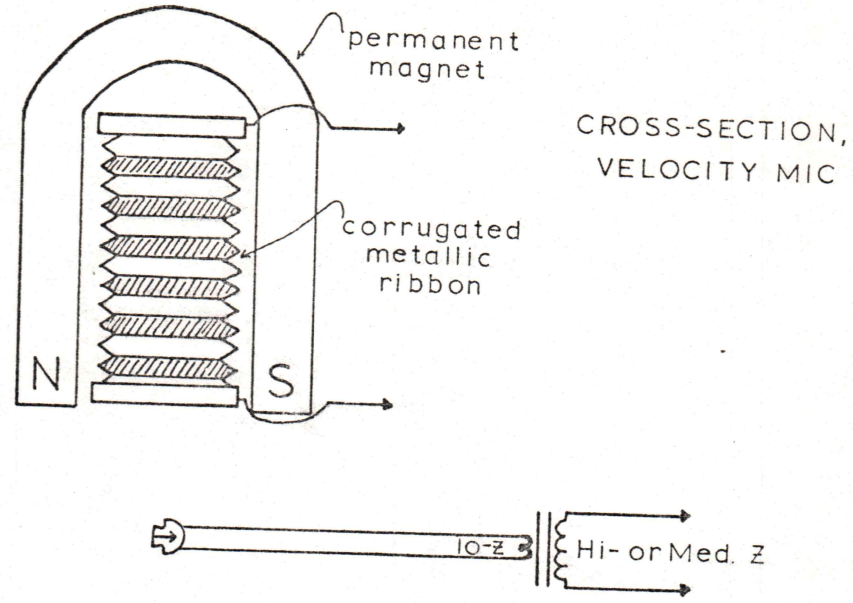


Figure 2-22. Velocity microphone and typical circuit.

factor, a preamplifier or cathode-follower stage is generally housed in the same case as the microphone itself.

The principle of operation of the condenser microphone is essentially that of a two-plate variable capacitor—the diaphragm and back plate being the equivalent of the two plates. A charge applied to the plates varies as they are brought closer to or farther away from each other. The flexible diaphragm is placed into motion by sound waves which change the capacitance by varying the air-gap. Condenser microphones require a potential to be applied to the plates. This potential generally amounts to several hundred volts and results in a charging current being caused to flow through a high resistance paralleled with the capacitor plates. Figure 2-23 illustrates the construction and typical circuitry of a condenser microphone.

A voltage drop is thus caused across this resistor, paralleled to the condenser microphone, and is subsequently applied to the

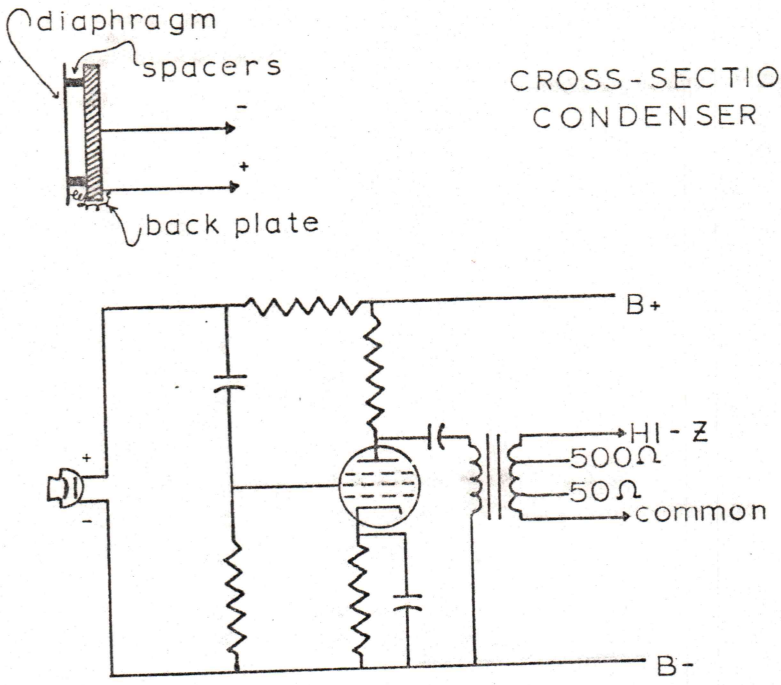


Figure 2-23. Condenser microphone and typical circuit.

input of the preamplifier. The voltage drop corresponds to the original sound waves in intensity and frequency and thus are the sound waves reproduced electrically. Condenser microphones are bulky to use, since they must be accompanied by a power supply to provide the required polarizing and operating voltages for the vacuum tube and the condenser assembly itself. Multiconductor cables are always required between the condenser microphone and its associated power supply. The condenser microphone's frequency response capability is from 20 to 18,000 Hz, and its employment for high-quality reproduction of music is recommended, if cost is not a critical factor. Its usefulness in investigative sound application is extremely limited, although one surveillance transmitter employs a condenser microphone as the heart of its frequency-modulated transmitter.

The Vibration Microphone (Contact Units)

This type of microphone is generally a crystal or a magnetic unit shock-mounted in a sealed damping mount. It generally has one surface exposed to the sound source and may bear directly against the vibration source or utilize a shaft or "spike" to carry the vibrations to the sound unit. Primarily, these microphones are used for amplifying the sounds of stringed musical instruments or for industrial applications for studying the running sounds of motors, machinery, running liquids in conduit, et cetera. They have a very definite application in investigative sound work in that they may often be used when it is impossible to install another type of microphone inside a room.

Figure 2-24 shows four types of vibration or contact microphones. Inside the shock-mount will be found a sensitive crystal or magnetic sound element which may or may not bear on a polished, sharpened shaft. This shaft serves as an armature to conduct vibrations from the wall to the microphone. When the contact microphone is not provided with a shaft, it still may be employed by cementing, or otherwise affixing, it to a window-

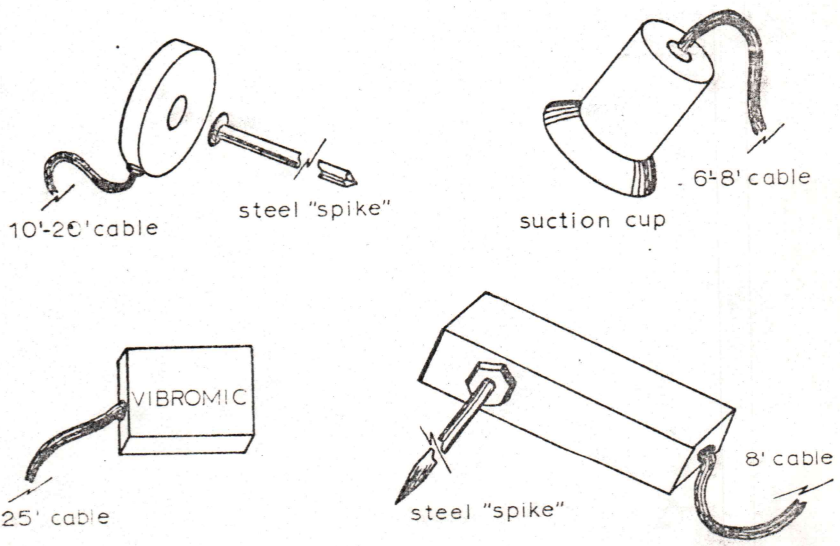


Figure 2-24. Various forms of contact microphones.

pane or other thin panel. These microphones, also known as wall-contact or spike microphones, are generally used in contact with a wall of the room inside which it is desired to monitor or make recordings.

A typical installation would be made by securing a room next to the room in which the subject will conduct conversations. By use of a magnetic stud locator (available inexpensively at most hardware stores) or by gently thumping the wall when the subject is elsewhere engaged, space in the central portion of the wall, between the studding, is located and marked. A ¼ inch hole is then bored through the investigator's side of the wall. The spike of the contact microphone is inserted in the newly-bored hole and brought to rest against the interior of the subject's side of the wall. If not already attached to the microphone, the spike is then affixed to the pickup unit. In some models the shaft is threaded, while in others the shaft is flattened on the microphone side and the pickup unit is held against it by rubber bands or tape.

The wall of the subject's room serves as a large diaphragm and sends minute sound vibrations through the shaft to the contact microphone. Care should be taken to insure that the shaft does not touch the sides of its hole on the investigator's side of the wall. A great loss in sensitivity might result if the shaft were permitted to transmit vibrations to the wall, instead of directly to the pickup unit. In addition, effort must be made to hold to a minimum the noise in the investigator's room, since it will be found that these sounds will be recorded with as equal fidelity as the sounds occurring within the subject's room.

In certain cases it may be necessary to employ a short shaft and apply it directly against a panel of an adjoining door. When the point of the shaft is first pressed against the surface it will bear upon, it is best to remove the pickup unit to avoid damage from physical force. Figure 2-25 illustrates a typical installation and method of supporting the microphone with tape or rubber bands and tacks.

A prime point to keep in mind is the fact that the output of this contact microphone should be preamplified before it reaches

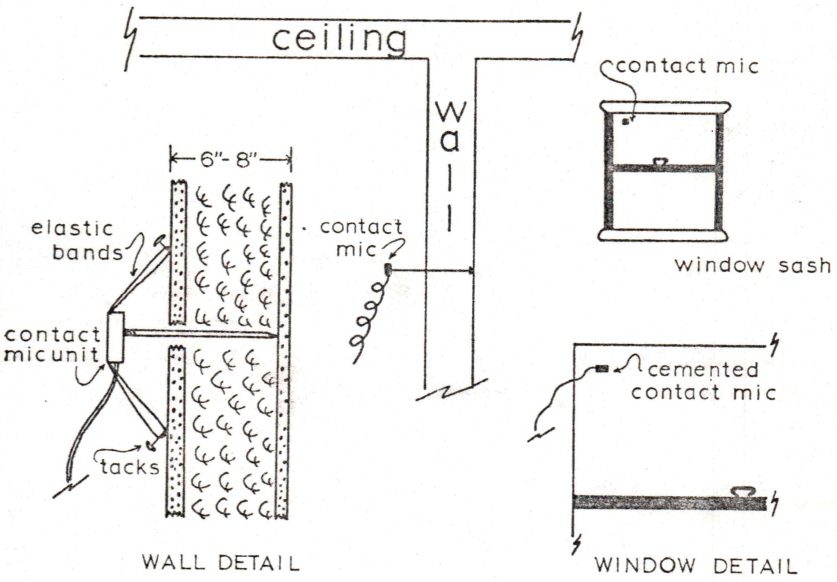


Figure 2-25. Contact microphones in use.

the recorder. Either a battery-operated or a line-operated preamplifier may be used, as long as the impedances are matched.

Directional Microphones

There are three types of directional microphones which have been put to a limited use in investigative sound work. These are the parabolic microphone, the "shotgun" microphone and the "machine gun" microphone. These microphones are designed so that they are able to selectively pick up sounds at a greater distance than standard microphones. It is the opinion of the author that they have been greatly overrated in their capabilities and that their reputation has grown steadily with each telling by someone who has "heard how they are used."

1. The Parabolic Reflector. Perhaps the most common of these directional microphones is the parabolic reflector employed with a sensitive microphone unit. Efficient in the recording of bird calls and insect noises, and sometimes for marching band music, the parabolic reflector does not fare well in the recording of voices for investigative purposes. The reflector itself, shown in

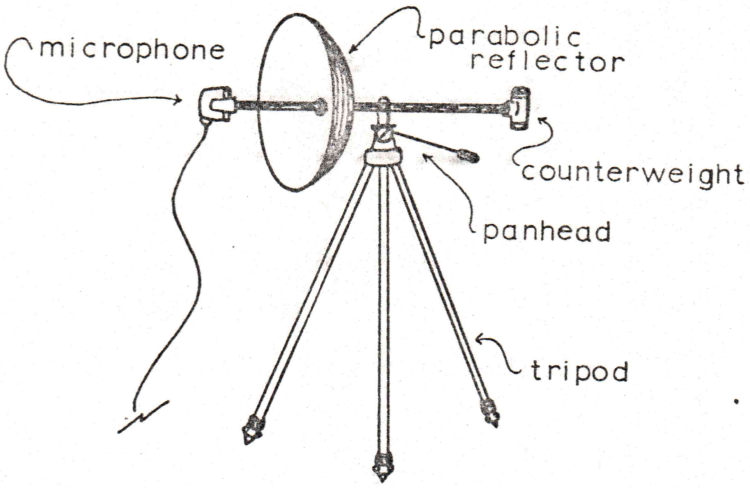


Figure 2-26. Parabolic reflector microphone.

Figure 2-26, is generally a dish or bowl of spun aluminum fashioned into a parabola. The diameter of the bowl determines its best frequency handling capabilities, while its depth and curve regulate the "focal point" for purposes of microphone placement. The microphone is fixed in a plane axial to the center of the inside of the parabola, with the open side of its sound element facing the apex of the dish. The microphone is generally positioned so that it may be moved along the axial plane in order to "focus" upon the sound source. In operation the reflector is carefully aimed at a nonmoving sound source and the microphone is moved back and forth until the proper "focus" is obtained, while the operator monitors with his amplifier and headphones. In principle, the sound waves travel across the distance between the speakers and the parabola, strike the parabolic curve and are reflected into each other a constant number of inches forward of the center of the dish. The microphone is moved so that its diaphragm is placed adjacent to the apex of these reflected sound waves.

In designing a parabolic reflector, one must remember that sound waves have a peculiarity of diffracting around an object that is approximately equal in size to the sound wavelength. Thus

the diameter of the reflector should be slightly greater than that desired to adequately reflect the sounds which it is desired to record. Parabolas must be quite large to record low-frequency sounds. Parabolas three feet in diameter are very poor reflectors of sounds below 300 to 400 Hz, while the higher frequencies are more efficiently reflected.

Using the formula

$$D = \frac{v}{f}$$

where D = diameter in feet
where v = velocity (approximate) of sound—1,200 fps (actually it is 1,130 fps at 20° C)
f = frequency of sound waves it is desired to reflect

We find that a reflector to be used with frequencies of approximately 100 Hz should be 12 feet in diameter. A 24 to 48 inch reflector would handle 500 Hz, while a parabola should be 6 feet in diameter to efficiently reflect frequencies on the order of 200 Hz. A 40-inch reflector with a 10-inch focus has been found to be satisfactory and, under favorable circumstances, has been found to result in a gain of over 20 dB over a standard microphone employed in the same circumstances without a reflector. It has also been found by the author that voices picked up by the smaller diameter reflectors are heard with considerable distortion, due to the loss at each end of the sound spectrum and associated harmonics.

It is wise to coat the reflector on the reverse, or on both sides, with a sound deadening compound such as automotive undercoating. In addition, this coating reduces the finish of the spun metal so that it is less noticeable. With the larger parabolic reflectors, it is best to mount them on a tripod so that they may easily be rotated. Cross winds and random sounds, such as surf noises, truck engine rumbling and any object moving across the "line-of-sight,' completely cancel out the speech of the subjects. Another disadvantage is obvious. Picture oneself and one's as-

sistants carting a tripod, an amplifier, associated coils of cable and a 4-foot diameter, black "radar antenna" dish across a hotel lobby.

One useful case is where it is desired to record the conversations in a room directly across an alley from the investigator's room. Provided that the subject leaves his window open, even slightly, and there is no wind or other noise from the alley, a satisfactory recording may often be made. Of course, it may be easier to affix a microphone to a long fishpole, or extensible whip antenna, and secure it so that it projects across the alley in close proximity to the subject's window—the technician must decide the best technique to employ. If some place to hide the parabola is available, recordings may be made at the beach or in any situation where there is unobstructed space between the parabola and the subjects, where the winds do not blow across or away from the parabola and where there are low ambient noise levels. A fine silk or nylon mesh windscreen across the face of the microphone or covering the whole parabolic reflector may prevent the wind "roaring" from interfering. The recorder, for most efficient results, should have a signal-to-noise ratio of over 50 dB, or a preamplifier should be used.

2. The Machine Gun Microphone. This microphone, resembling a Gatling machine gun, consists of a bundle of long metal tubes, of small diameter, fastened together with bands and with a microphone attached to one end. Models have been available, made of either ¼ inch or ⅜ inch tubing, consisting of approximately fifty tubes varying between 1 inch and 6 feet in length. The microphone is surrounded by sound deadening material and is clamped in a housing attached to one end of the tube bundle. In theory, sounds which occur directly forward of the microphone will be transmitted simultaneously down the bore of the tubes and will arrive at the microphone in phase. Sound waves which occur in an azimuth away from the direction the bore of the tubing is aimed will have to travel varying distances to reach the microphone and will therefore reach the microphone out-of-phase and be canceled out. These microphones may be expected to exhibit a loss of over 10 dB and should be used with a

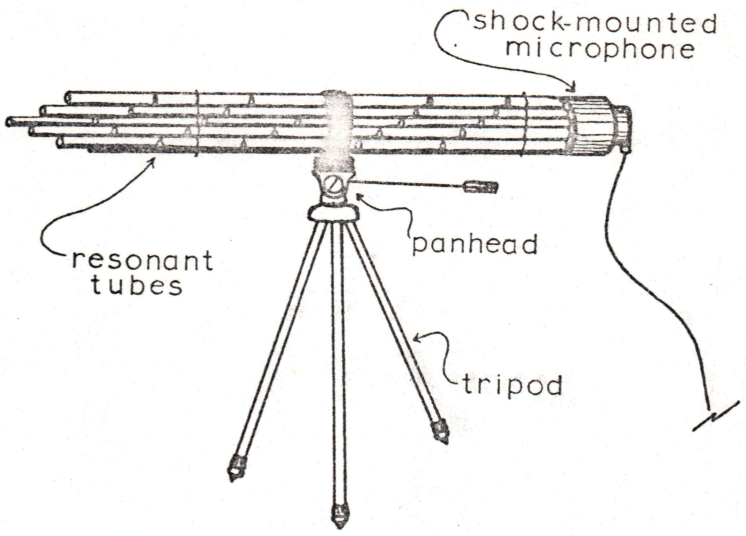


Figure 2-27. Machine gun microphone unit.

sensitive preamplifier. Their quality leaves much to be desired. Figure 2-27 illustrates a machine gun microphone. At one time Western Electric Company manufactured these units in a limited number but has since discontinued their production.

3. THE SHOTGUN MICROPHONE. Utilizing the same principle as the machine gun microphone, but attacking the problem in a slightly different manner, the shotgun microphone was developed. This unit shown in Figure 2-28, employs a single tube with a microphone attached to one end. Slots are cut in the wall of the tubing, parallel to the long axis of the tube, in order to prevent the wall from resonating and to lower the "boom" and echo. Again, considerable loss may be anticipated, and a preamplifier is recommended if any results at all are to be expected. Most investigative sound technicians have little praise for the quality afforded by presently available low-cost directional microphones. Electro-Voice has introduced a model of high efficiency which is available at a price of over $1,500, while Sony has recently announced a condenser microphone model, only two feet in length, selling for $1,000.

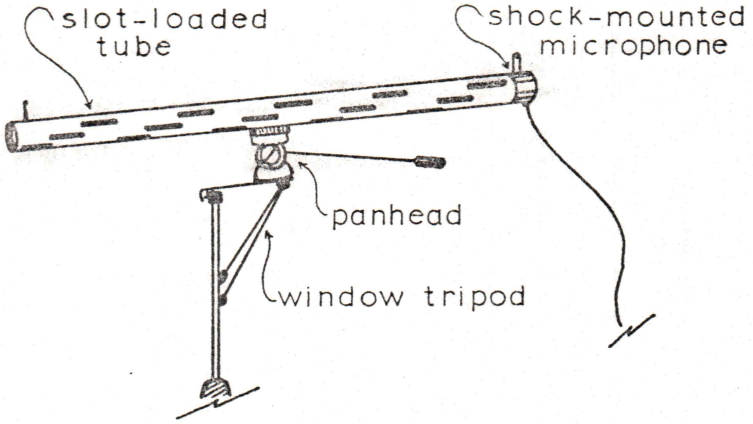


Figure 2-28. Shotgun microphone unit.

Induction Pickups

Although their use is restricted to the monitoring of telephone and intercommunication systems, induction coils or pickups are best considered here with all the other types of sound pickups. These units have been widely used by individuals desiring to record their own telephone conversations and have much to offer for a hasty recording or for occasional use around an office.

Induction coils are credited, in stories of fact and fiction, with a wide variety of marvelous powers. Some wishful thinkers claim that they have units which can pick up a telephone conversation up to 25 feet from a telephone. Others vow that they have made usable recordings from, or have monitored, public telephone booths from the same distance. The principle of operation of these units is that alternating currents in the coil of a telephone are induced in the coil of a unit held in close proximity to the telephone coil. Theoretically, an induction coil will pick up telephone conversations whenever the coil is placed within the field of the telephone circuit. Similarly, the induction coil will also pick up any other a-c field in which it is placed. This includes the a-c field of the sound recorder used in conjunction with the coil. Usually the noise of an a-c field will begin to fall off when the coil is removed to over three feet away from the source of the a-c field. The coil, however, is highly directional

in its pickup characteristics, and a coil held just a few feet away from an a-c field may be "tuned-in" on the field by rotating the coil's position.

Consider that the influence of the a-c field falls off when the coil is removed to over 3 to 5 feet from the source of the a-c field and remember that what the induction coil picks up in telephone use is the a-c component of the circuit. Since the a-c field surrounding components of a typical telephone circuit is relatively weak and realizing that most of the other a-c fields to which the coil might be exposed are correspondingly strong, then what distance away from the telephone instrument or line may the coil be placed before the weak a-c component begins to drop off?

In addition, every a-c power line in use exhibits a relatively strong field and one cannot travel far these days without coming near an a-c line. They are found in walls, ceilings, floors and in the air and earth around us. Virtually every public telephone booth is equipped with a-c power for lighting and ventilation. Most intercommunication systems employ a-c line-operated amplifiers and subsequently employ multiconductor, shielded interconnecting cable. It is difficult, to say the least, to induce a conversation in the vicinity of a shielded cable.

Induction coils are often used, however, and the investigative sound technician would be wise to keep a few in his tool case. Conversations may be induced either from the network in the base of the telephone, the ringer coil, or from the receiver end of the telephone handset. One advantage of the handset variety is that they may be positioned for loudest reception; in addition, they are generally smaller. Models are available that slip on over the receiver end of the handset or that are held in place by a rubber suction cup. Figure 2-29 illustrates several induction telephone pickups. All units available are of the high-impedance type and may be used directly into high-Z "microphone" or "Radio-Phono" input of the standard tape recorder.

Induction coils of the flat or tubular type may also be used against ringer boxes on older telephone systems or may be wrapped between conductors of the line. When purchasing the

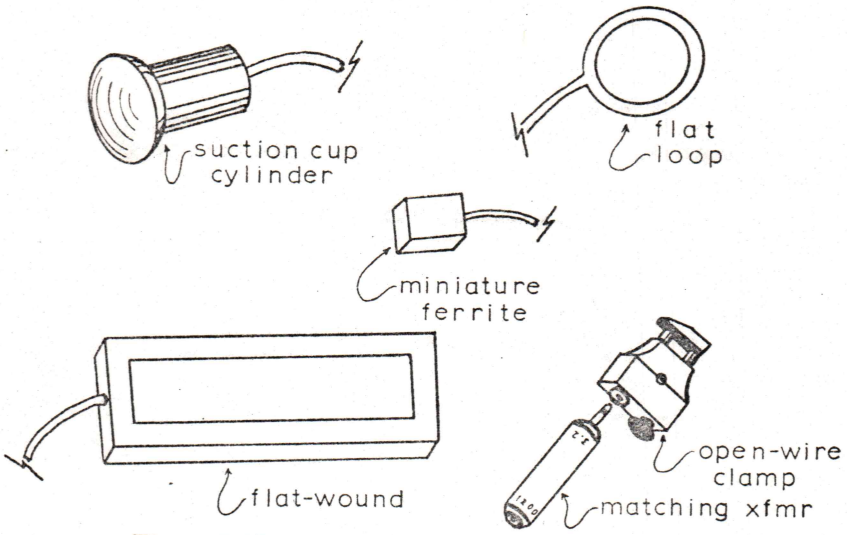


Figure 2-29. Various induction telephone pickups.

type of coil which slips over the receiver end of the handset, realize that different sizes are available to fit the Western Electric Company's model 300-series (older type in use in the United States). The author has found that one each of the slip-on variety, a reliable suction-cup model and one of the flat units provide the maximum utility. Generally speaking, induction coil telephone pickups are most useful for making a recording at the telephone, with the full knowledge of the participant, in cases where time or circumstances do not allow the installation of a wiretap.

OPERATING DIRECTIONS

Up to 25 feet of shielded, single-conductor microphone cable may be used as an extension for induction pickups. Place the coil under the base of 300-series telephone, parallel to the position of the handset when it is hung up. On the 500-series models the coil is most effectively used against the receiver portion of the handset. The coil may be tried on the right side of the base, near the rear (with the set facing the operator) or underneath the base. Positioning is best established by experimentation. Wall-mounted sets require the coil to be used on the side, or at the rear, of the

set. The old 200-series model telephones require the coil to be used on the wall-mounted subset. In pay booths, the coil is employed against the receiver in the handset. When used in conjunction with an auxiliary, battery-operated amplifier and a recorder, conversations may be picked up from one public telephone booth to another adjoining one. The coil must be carefully positioned for best results.

Supports, Booms and Fittings

Most cased microphones produced in the United States are provided with ⅝ inch-27 threads for mounting purposes. In purchasing accessories to be used with any given microphone, attention must be given to obtaining the proper fitting adaptors. Available for microphones are flexible goose necks for positioning of the microphone when it is attached to a stand or other fixture; cable hangers for looping coiled microphone cables onto the support stands; snap-on microphone attachments for quickly detaching the microphone from its stand; and cable or mike stand "on-off" switches.

In addition, various floor stands, desk stands, boom stands and banquet stands are available. The reader is referred to catalogs available from any electronics wholesale house for a more complete account of these accessories.

Cabling Requirements

Requirements for cabling various types of microphones are listed below, after the variety of microphone shown:

1. *Carbon Microphones.* Most any two-conductor cable may be used. Smaller diameter wire, easier to conceal, may often be disguised by using telephone company's JKT inside station wire, or television 300-ohm flat, twin-lead. Length is relatively unlimited; and it is not normally necessary to use shielded cable.

2. *Crystal Microphones.* Single-conductor, shielded cable not over 25 feet in length; such as Belden No. 8401, 8410 and 8411.

3. *Dynamic Microphones.* Two-conductor, shielded cable up to 500 feet in length for 50-ohm microphones, such as Belden No. 8412, 8422 and 8428. For high-impedance microphones, cable should be no more than 25 feet in length. Short, unshielded wires

may be run between the microphone and the shielded cable in order to afford better concealment, but they must be kept as short as possible.

RECOMMENDED INVESTIGATIVE MICROPHONES

Certain microphones have much to commend them for use by the investigator, while others are virtually useless. Depending upon the use to which the microphone is put, each microphone has both strong and weak points which must be considered in selecting a pickup for a specific task.

Below are described microphones, which are highly recommended for use in technical surveillance work because of their common utility value:

1. *Carbon Microphones.* Probably the best and most easily accessible microphones are the Western Electric F1 and T1 carbon microphones removed from telephone service. They are widely available on the surplus market or can be procured new from sources listed in the Appendix.

2. *Crystal Microphones.* Most any small unit which can be easily concealed can be recommended without further consideration. Typical of this microphone is the Shure Model 777 "Slim-X" microphone or the Shure Model 76B lapel microphone, which has a higher output. Also of utility value is the Electro-Voice Model 924 and the Turner Models 80 and L-100.

3. *Dynamic Microphones.* Without argument, the American DD4 and D801 dynamic, the Sennheiser, the Knowles and the Tibbetts microphones are superior for use in technical investigations. They are small and easily concealable and may be used with up to 500 feet of cable. Their fidelity is more than adequate. In the opinion of the writer, these microphones are the best available for general investigative sound work. They must be matched to the recorder or amplifier, noting that their impedance may be 50 or 1,000 to 2,000 ohms.

4. *Magnetic Microphones.* The Shure MC series of miniature magnetic microphones are quite useful and are small enough (approximately one inch in diameter) that they can be concealed almost anywhere. Remember that they have an impedance of

1,000 ohms and will have to be matched to the amplifier or recorder. The author has tested this microphone with up to 250 feet of unshielded extension cable feeding a 1,000-ohm impedance transistor amplifier, with adequate results. The use of shielded cable would result in less stray hum pickup and produce a more satisfactory recording.

5. *Contact Microphones.* The "spike" microphones specially distributed by sources listed in the Appendix are the best available in the United States and produce superior recordings when employed under the proper conditions. They should be used with an external or internal booster amplifier in order to provide an acceptable signal level. In addition, care must be exercised to install them properly, since a poorly installed unit will render unsatisfactory results.

SOUND RECORDERS

The magnetic sound recorders of today are produced using basic principles developed by the noted radio experimenter, Valdemar Poulsen, in 1898. The "Telegraphone," invented by Poulsen, became the forerunner of all modern magnetic recorders. The principle of operation is simple. Steel wire is drawn past a permanent magnet, while voice currents are fed to coils mounted on the magnet pole pieces. Voice currents are generated in a pulsating wave and magnetize the wire according to their intensity. When the wire is passed through a similar magnetic playback head, with associated amplifier, a reproduction of the original sound is heard.

During World War II stainless steel tape was used in the United States to record voice frequencies on a limited basis. Disc recorders were in wide use for broadcast and general investigative use. Sound recorders of the embossed film type were used by intelligence agencies and communications monitoring units. These recorders, the AN/UNQ1 series, utilized a magnetic cutting head bearing a scriber that embossed magnetic impulses on the longitudinal axis of a 60-foot endless belt of 35 mm film. Reproduced results were noisy, as was the physical operation of the film recorder. The author coined the name "threshing

machine" for the embossed film recorder, and anyone who has ever heard it will sigh in fond remembrance. In those days it was important for the investigator to obtain a room far enough away from the subject's room so that he could not hear the wild thrashing of the recorder!

Stainless steel wire next made its debut as a recording medium. Wire recorders employed wire with a diameter of 0.004 inch. Their use became widespread, but since frequency range was limited, they were quickly supplanted when magnetic tape recording was introduced in the United States. Wire recording is still employed in some dictating machines and in one subminiature German recorder.

Germany developed and began to use magnetic tape recording during World War II, and at the close of the war the principles were quickly seized upon by the Allied countries. First used was the black magnetic iron oxide coating on paper tape, followed by improved types of red magnetic iron oxide applied to plastic tapes. This idea is in widespread use today.

The magnetic tape is stored on a supply reel and passed over the poles of the magnetic recording head by constant-speed tape transport linkage coupled to a take-up reel. A recording amplifier transmits the audio input to the magnetic poles of the recording head. These fluctuations create a variable magnetic field which causes realignment of the tape's magnetic iron particles. (See Figure 2-30 for a functional drawing of the magnetic recording head.)

Tape Heads

Magnetic tape recorder heads are made in three types: record heads, playback heads and erase heads. Professional grade recorders utilize the three separate heads for greater efficiency and response. Moderate-priced recorders employ the same head for recording and playback and a separate erase head.

Playback, or reproduce, heads are similar in construction to record heads and pick up, by induction, the magnetic fluctuations impressed on the recorded tape. As the tape passes over the playback head, the magnetic impulses induce a field in the coils attached to the magnetic pole pieces of the playback head.

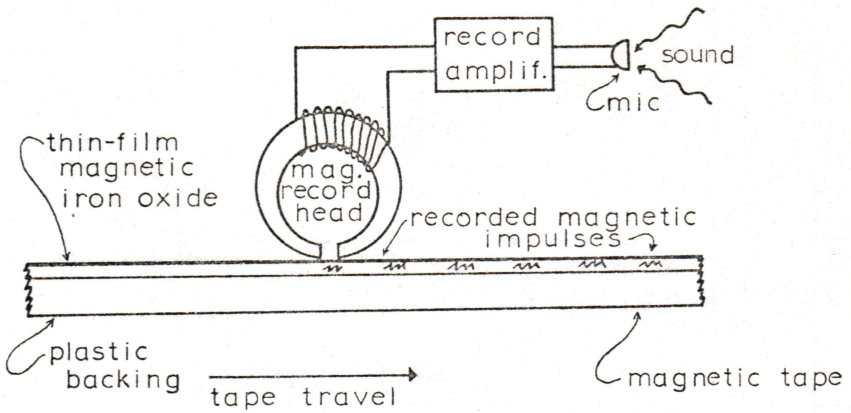


Figure 2-30. Function of the magnetic tape head.

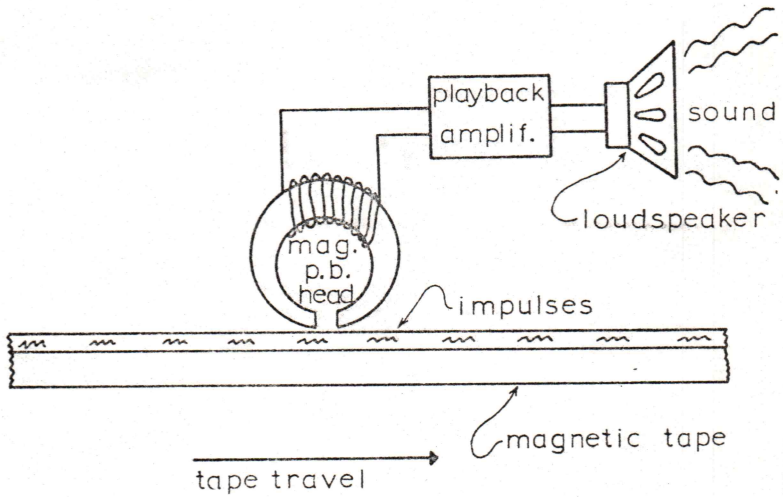


Figure 2-31. Function of the magnetic playback head.

Figure 2-31 illustrates this function. The playback head sends these voltage variations through the playback amplifier, wherein they are amplified for reproduction. Some recorders utilize portions of the playback amplifier for the recording amplifier by selective switching arrangements.

Erasing functions may be accomplished by either d-c or a-c. When the tape is pulled through a strong magnetic field of stable intensity or through a field of high-frequency alternating current,

the recorded magnetic signal is completely obliterated. The d-c erase leaves a characteristic hissing noise on the tape and is generally considered objectionable. The a-c erase head uses a very high-frequency current (such as 100 kHz) that creates a rapidly-changing magnetic field that results in reducing each particle past its magnetic saturation point. Thus is the recorded signal removed. These magnetic particles on the recording tape are left in a randomly magnetized position, neutral for all practical purposes. This method is also known as a supersonic-signal erase. Figure 2-32 shows a typical high-frequency a-c erase head.

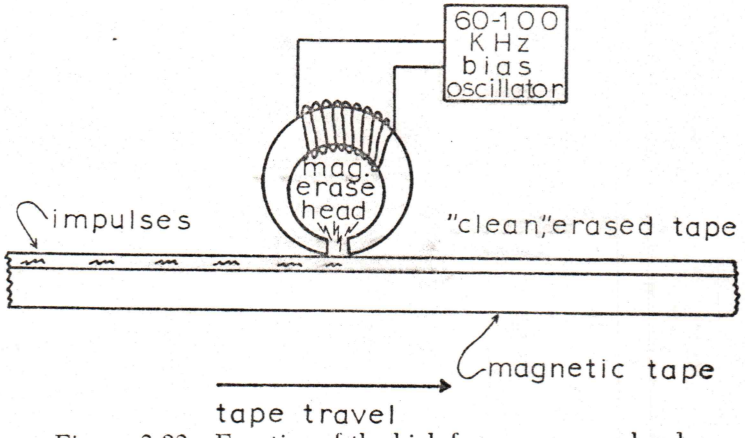


Figure 2-32 Function of the high-frequency erase head.

Tape Transport

Probably the most important single component in the entire recorder is the tape transport or drive mechanism. Constant speed is absolutely necessary. The better recorders employ three separate motors: the supply reel motor, the take-up reel motor and the tape drive motor, which pulls the tape over the recording head.

Capstan drive is normally employed, since direct wheel drive would not compensate for the changing diameter of the reel. Power is generally transmitted by flat or oval belts and rubber-rimmed wheels. Belt and wheel drive permits some slippage in the event that tape tension becomes too great and reduces tape

breakage. Tape tension must be uniform to an extreme degree of tolerance, otherwise painfully audible "wowing" results. Tape transport speed is adjustable in most modern instruments and may vary between 15/16 inch per second and 30 inches per second. Reference or strictly voice recorders may use 15/16 inch per second, and recorders to be used for higher quality voice recordings use 1⅞ or 3¾ inches per second. Home music recorders generally employ 7½ inches per second, while broadcast-quality instruments are capable of recording at 15 or 30 inches per second. Normally, moderate-priced recorders offer a switching arrangement whereby the recordist may select either 3¾ or 7½ inches per second. Frequency response is directly proportional to tape speed. As a rule of thumb, with the new narrow-gap heads, one may safely estimate that the upper frequency response may be gauged by multiplying the tape speed by 2,000. With this rule then, a tape speed of 3¾ inches per second would cover an upper frequency limit of 7,500 cycles, while a 15 inch per second speed would handle about 30,000 cycles. This rule is not accurate but serves as a rough estimate for tape speed selection.

Playing times of tape reels vary with the size of the reel, the length of the tape supply, the recording speed utilized and the thickness of the tape itself. Shown below is a table that illustrates useful time available under these different conditions.

TABLE V

TAPE PLAYING TIME (PER SIDE)—½ mil "TENSILIZED" TAPE

Tape Speed	Tape Length (ft) 300	600	1200	1800	2400	4800	*Freq. Response*
15/16"	1 hr	2 hr	4 hr	6 hr	8 hr	16 hr	40- 4,000 Hz
1⅞"	30 min	1 hr	2 hr	3 hr	4 hr	8 hr	40- 8,000 Hz
3¾"	15 min	30 min	1 hr	1½ hr	2 hr	4 hr	40-16,000 Hz
7½"	7½ min	15 min	30 min	45 min	1 hr	2 hr	40-20,000 Hz

American tape reels are produced in the following sizes: 3 inches, 5 inches, 7 inches, 10½ inches and 14 inches. The amount of tape they hold will vary, depending upon tape thickness. Recording tape is supplied in 2 mil, 1½ mil, 1 mil and ½ mil sizes. The heavier tapes are much stronger, of course, and it is not possible to get as much of a heavier tape on a particular size reel

as it is a thinner variety. Late tape types are made with a polyester film backing, which enables greater tensile strength. Acetate types, although heavier, are still sometimes employed.

Most moderate-priced recorders are dual-track instruments and conserve on tape length by providing for reversal of the tape after it has completely passed over the recording head. Utilizing only the top edge of the tape, the recording tape has the whole bottom edge which may be recorded on when the reel is turned over and run through the recording head again without rewinding. Dual-track units offer the same frequency response as single-track units, but with a slight loss in recording volume level. One great advantage of the single-track unit over dual-track types is that recordings may be edited by cutting out sections and splicing the desired portions together. This may be done with dual-track tapes, but the portion of recorded material in the opposing track will be lost.

Tape Recorder Amplifiers

Tape recorder amplifiers are quite similar to the general amplifiers which have been discussed in preceding portions of this paper and consist of preamplifiers, the general amplifier and volume-level indicator. Generally, push-pull types are employed to take maximum advantage of low hum and distortion characteristics. The preamplifier stage provides extra gain for the low-level signals of microphones and boosts equalization losses. Volume level indicators for observing recording level may be one of the following types: single or dual neon glow lamps; electron-ray "eye" tube; or volume-level recording meter, calibrated in "VU" units or decibels, with reference to a 600-ohm line. Professional recorders generally employ the VU meter, since it is considerably more accurate than either of the other types. Neon glow lamps, provided they are accurately calibrated and the recordist is familiar with their characteristics, are perfectly acceptable for investigative sound applications.

Basic recorders used for general investigative services should possess the features listed below, in order to enable satisfactory operation:

1. Constant speed transport, lowest wow, flutter and noise specifications.
2. Separate recording, playback and erase heads.
3. Multi-speed, dual-track operation 15/16"–1⅞"–3¾"–7½".
4. VU meter recording level indicator.
5. High-speed forward and rewind.
6. Should accept up to 7-inch reels.
7. Room inside case for added investigative circuits.
8. Tape head monitoring facilities and AB comparison switch.
9. Lightest and most compact unit embodying the above features.
10. Low- and high-impedance inputs.

Tape Transport Mechanisms

Virtually all magnetic tape recorders necessitate constant speed tape transport mechanisms operating through the phases of recording and playback, for reproduction of maximum fidelity. The transport must pull the tape past the heads evenly, at a constant rate and under equal tension. The tape must not move except in the indicated direction.

Two conditions are caused by poorly designed or improperly operating transport drives: flutter and wow. In tape reproduction, the momentary variation in pitch of a sustained musical note is called "wow," while "flutter" is that variation, not amounting to wow, resulting in overall distortion. Since tape is slightly elastic, any momentary stretching as it passes the heads causes flutter, which results in an unpleasant feeling in the ears of the hearer. Flutter may also be caused by vibration of the tape against the heads due to failure of the lubricated surface, a rough-surfaced tape guide, dirty heads or a flattened portion of the pressure roller. Dirty pressure pads, which become impregnated with dirt, wax and powdered iron oxide, can cause flutter when their defective condition falls short of causing pressure pad chatter or squeal.

Perhaps the most common type of drive mechanism is the capstan drive assembly. Shown in Figure 2-33, the capstan drive may be activated by multiple belts, cog-belts, rubber drive wheels

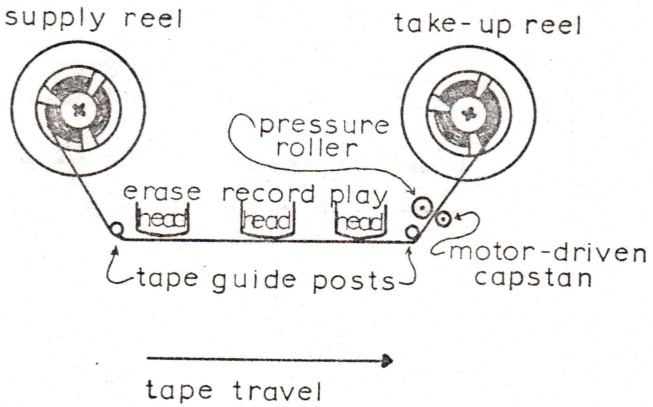


Figure 2-33 Motor-driven Capstan assembly used in tape transport mechanism.

or by direct motor drive through a flexible power shaft. When thus driven efficiently, the capstan transport serves to turn true at constant speed, to impose on the tape over five times the force necessary to neutralize the inertia of the transport system and to resolve any variations of the system in conjunction with a balanced flywheel.

Rubber pressure rollers are usually about three times as wide as the magnetic tape and carry the tape between the surface of their roller and the capstan. Portions of the roller not in direct contact with the tape are forced against the moving capstan. In this way the motor drives the capstan, which in turn moves the rubber pressure roller carrying the tape forward. In an attempt to influence the constant-tension resistance of the tape transport system, older model tape recorders employed the application of d-c to a torque-drive motor in order to influence the proper drag. Since the adoption of the standard N.A.R.T.B. tape reel hub (wherein the diameter of the reel is close to two times the hub diameter), these special torque motors are no longer necessary in standard use.

On expensive instruments three motors are generally employed: the capstan-drive motor, the supply reel motor and the take-up reel motor. Less expensive recorders utilize a variety of

belt drives, coupled with clutch and shifting mechanisms, in order to secure rates and fast speeds forward and rapid reversal. Most recorders employing Armour Foundation patents utilize a friction clutch of the gravity type to maintain normal tape tension as the diameter of the tape level on the reels increases and decreases. Other tape recorders utilize slipping-belt or belt-shifting devices, in addition to unique clutches, in order to permit the use of only one motor in the tape transport mechanism.

The better recorders employ synchronous motors in their drive systems in order to secure maximum tape speed stability in the face of line voltage fluctuations. Synchronous motors operate at a standard speed, provided that the frequency of the line current remains constant. Synchronous motors permit fluctuations in line voltage, within limits while operating at a constant motor speed. If circumstances are anticipated, however, in which fluctuating line frequency might be encountered, perhaps the induction motor would be a better choice. Another solution to the problem is the use of power packs operated by storage batteries or by line current in conjunction with a separate oscillator which controls the frequency of the generated current.

Signal Erasure

Magnetic recording tapes may be electronically erased and used over and over again, which is a factor contributing to their widespread adoption. Degaussing and wiping are terms synonymous with erasing, as used herein and in the general field of sound recording. By electronically wiping away all the magnetic impluses held in the tape, the tape is left in a "clean" condition ready for superimposition of the next signal to be recorded.

Erasure is most commonly accomplished by means of a-c, since d-c erasure has been found to leave a high noise content on the tape. Alternate a-c saturation is effected, in one magnetic direction at a time. As the tape leaves the demagnetizing field, it is exposed to succeedingly narrower erasing fields until it is magnetically neutral when it arrives at the recording head. The a-c erase heads are generally two-coil units, made of laminated

silicon steel with a very narrow gap which is filled with a nonmagnetic substance.

Built-in a-c erase facilities, included on most modern tape recorders, are generally efficient enough for nonprofessional applications, but broadcasting and professional users often employ bulk tape erasing devices. In some cases, recordists disconnect the a-c erase heads from their instruments. Bulk tape erasers consist of large a-c electromagnets which operate from a-c line current and produce essentially noise-free erasure. Use of a bulk tape eraser enables a much more usable signal-to-noise ratio. Their use in investigative sound applications is highly recommended from the standpoint of the better signal-to-noise ratio. In use, one plugs the eraser into the a-c line socket and turns it on; the tape reel is then brought slowly into its field. If the eraser is of the heavy type, bearing a spindle, the reel is placed on the spindle and rotated slowly several times in the same direction. While rotating the reel slowly, it should be carried upward and away from the electromagnetic field before the eraser is turned off. If the hand-held eraser is used, it should be turned on and, while rotating it in the air, brought slowly into contact with the tape reel. After several rotations, the eraser is lifted away from the reel, still rotating slowly, and carried upward and away from the reel of tape before the eraser is turned off. If this operation is conducted carelessly or if the eraser is turned off before the reel of tape is outside its field, magnetic fluctuations will be recorded on the tape. Bulk erasers heat quickly and should be kept in use only a few minutes at a time. The operator will wisely remove his wristwatch during this operation lest it be magnetized by the degausser.

Head demagnetizers are available which "clean" recording heads and operate on the same principle as the bulk eraser. Their use is recommended as a routine preventive maintenance operation if consistently superior recordings are desired.

It is quite necessary to establish a routine for cleaning the operating parts of a magnetic recorder if its best performance is to be expected. Following is a checklist for the routine preventive maintenance of any magnetic tape recorder.

Tape Recorder Servicing

1. Clean heads regularly by scrubbing the heads with carbon tetrachloride, thus removing dirt and tape residue from the tape slot.
2. Demagnetize the heads with a head demagnetizer about every eight hours to avoid loss of high frequencies and tape noise.
3. Ensure that reels are not warped, causing flutter.
4. Replace idlers and belting about once a year.
5. Lubricate only according to manufacturer's instructions.
6. Never leave mechanical switches in the "Drive" or "Play" position when recorder is not in use to prevent flat spots on rubber idler wheels.
7. Permit adequate ventilation of operating recorders.
8. Run all new tapes through the recorder in fast-forward before making recordings. Do the same to tapes that have been in storage for a while.
9. Store tapes in boxes, in cool locations of moderate humidity.
10. Check all plugs and connections for soundness, continuity and freedom from shorts.

This comprehensive treatment of audio systems should serve as a fundamental guide for the investigator interested in developing his skills in the use of electronic audio surveillance methods. In the examination of the succeeding chapters, the reader will find that some reference is made to the principles of sound systems and equipment discussed herein and should not hesitate to re-read such material as may assist in the understanding of the newly presented material.

Chapter 3

TELEPHONE SYSTEMS

In order to be able to work effectively with telephone and line devices, the investigative electronics technician must have a usable understanding of basic telephone systems. This examination of telephone systems must of necessity begin with a look at the basic components of telephony, the connecting wires and switching arrangements.

A telephone system contains speech transmission channels, telephones and signaling and switching apparatus, and its sole purpose is to guide the circuit which carries a separate conversation between two telephone stations. Telephones may be of two types: battery-powered and sound-powered. Sound-powered types have much lower efficiency, although they are useful in rapidly establishing two-way wire communications systems where none previously existed.

In this chapter we will consider the battery-powered telephone which may be found in either local or common-battery circuits. Since the purpose of the telephone is to extend the range of voice communication between persons, it must first convert the sound wave to an electrical wave, send the electrical wave over a pair of wires and finally reconvert the electrical wave to a sound wave so that the listener may understand the message.

TELEPHONE RECEIVERS

The basic telephone, as developed in 1876 by Alexander Graham Bell, was a sturdy telephone receiver utilized both as transmitter and receiver. This circuit consisted of a pair of wires with a receiver on each end. Figure 3-1 shows this circuit.

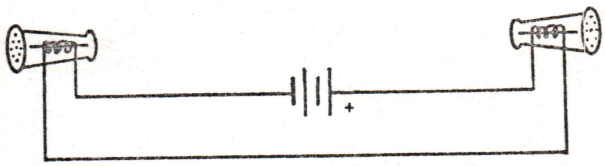


Figure 3-1. Basic telephone circuit.

In the receiver, the voice waves strike the diaphragm of the receiver, and the condensations and rarefactions of the air cause the diaphragm to vibrate. In back of the diaphragm is a permanent magnet and the magnetic lines of force from the north pole of the magnet are induced through the receiver coil and return to the south pole of the magnet. The number of lines of force depends upon the width of the air gap to be passed, in addition to the amount of metal in the path, and as the diaphragm moves back and forth by pressure from the sound wave, it changes the width of the air gap between the magnet and the diaphragm. The vibrating diaphragm makes the changes in the induced magnetic force lines of the receiver coil and causes the coil field to be sectioned by the varying lines of force. Thus is a varying electrical potential induced in the receiver coil, varying directly with the frequency of the transmitted sound wave.

This alternating current that has been initiated at the transmitting end of the circuit then is sent through the receiver coil at the far end of the circuit. The field set up by this activity varies the strength of the field of the permanent magnet, which alternates the attraction for the receiver diaphragm. The effect is that the diaphragm of the receiver and the transmitter vibrate almost simultaneously resulting in speech being heard in the receiver. Depending upon normal losses in the circuit, the amplitude of the receiver is less than perfect in its efficiency.

The modern receiver unit as produced by Automatic Electric Company, Kellogg and Western Electric Company is designed to be mounted in several types of telephones. Receiver coil windings are wound around Permalloy pole pieces which are, in turn, welded to cobalt-steel bar magnets encased in a frame of zinc alloy. The steel alloy diaphragm floats on a circular ridge and is secured solely by the pull of the permanent magnets.

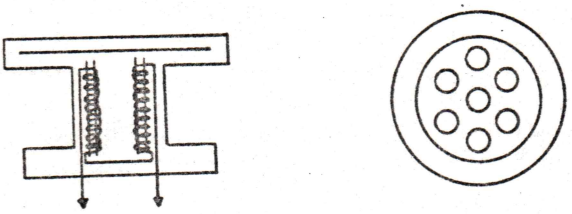


Figure 3-2. Modern handset receiver unit.

Common WECo models are the HA-1 (older types), HA-2 and the U-1 (later types). (See Figure 3-2.)

TELEPHONE TRANSMITTERS

After Bell had developed his original transmitter, which employed the principle of electrical energy created by the movement of a diaphragm in a weak magnetic field, it was observed that this method was inadequate over any except very short distances. Within a year following Bell's discovery the Blake transmitter was developed. It is this general type of transmitter which is in wide usage today. The Blake principle is based on the fact that varying the strength of an electrical current within the diaphragm causes audio frequencies to be converted to usable electrical impulses. It has a much higher output than Bell's original device. (See Figure 3-3.)

Direct current flows through the carbon granules in the cup, through the primary turns of the induction coil and returns to the positive battery terminal. The diaphragm is connected to a small carbon plate which is pressed up against the carbon granules in the cup, changing the pressure thereon through variations in sound waves striking the diaphragm. As the granules vary their

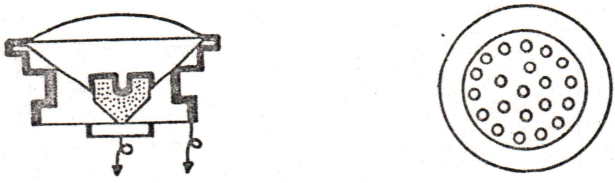


Figure 3-3. Modern handset transmitter unit.

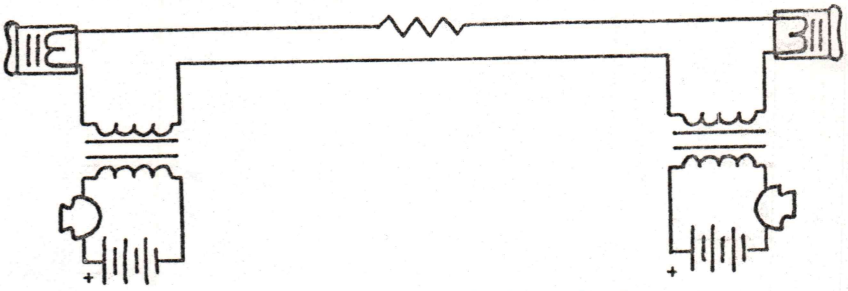


Figure 3-4. Simple telephone circuit.

closeness to each other, so varies the conductance of the d-c path through the carbon cup. Since these variations in conductance affect the battery's d-c current drain, they correspondingly produce an induced emf in the secondary turns of the induction coil. In this way is a-c caused to flow in the telephone circuit. As can be seen in Figure 3-4, the calling station may be heard in its own earpiece whenever voice current flows through the coil of its receiver. This induced reception is known as sidetone.

Modern transmitter units, such as those manufactured by Automatic Electric Company, Kellogg and Western Electric Company, are able to operate satisfactorily in any position and are of the direct-action type. The thin aluminum diaphragm is attached to a curved electrode which is seated against a gold-plated cup containing carbon granules. (See Figure 3-5.) The front electrode and the cup serve as the two electrodes to conduct d-c current. Most carbon transmitter units have a resistance of about 35 ohms. WECo refers to their transmitter units as the

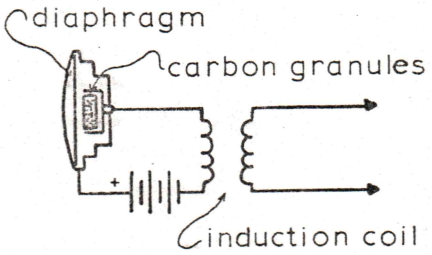


Figure 3-5. Basic telephone transmitter circuit.

G-1 (older type), the F-1 (intermediate type) and the T-1 (later type). In addition, a one-inch diameter unit, the N-1, is manufactured for head telephone sets, WECo type Number 52.

INDUCTION COILS

Telephone induction coils are transformers that function satisfactorily over the range of voice frequencies and are used to inductively couple two circuits. They are made in two types: the closed-core type and the open-core type. (See Figure 3-6.) Since the closed iron core type forms a complete loop around the coil, it provides a more efficient return for the magnetic lines of force. The open-core induction coil provides an air gap. Coils are made of insulated copper wire wound on a laminated steel core, which minimizes the power loss due to eddy currents. They have two or three windings with the terminals mounted on the frame. (See Figure 3-7.) The voice currents flowing in the primary coil cause voltages corresponding to the audio frequencies

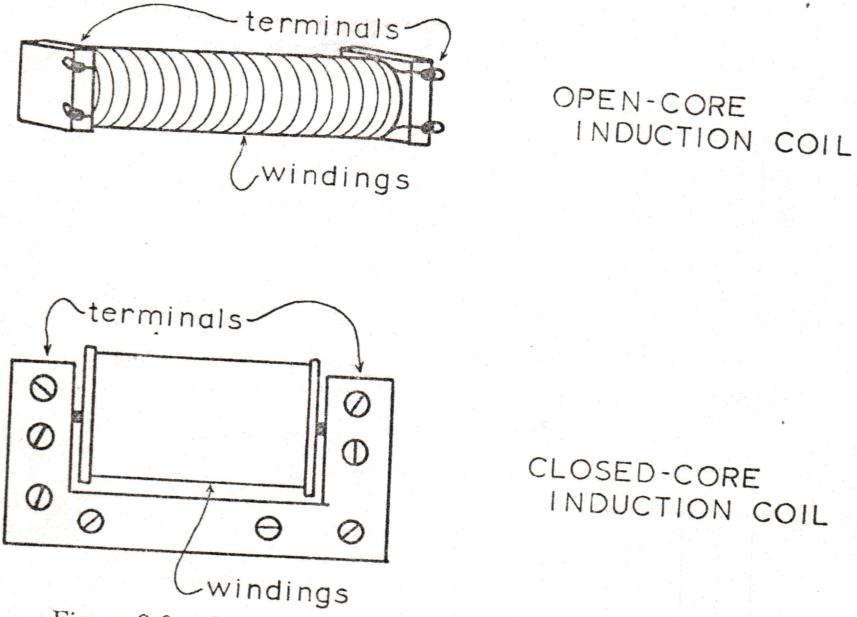


Figure 3-6. Open-core induction coil; closed-core induction coil.

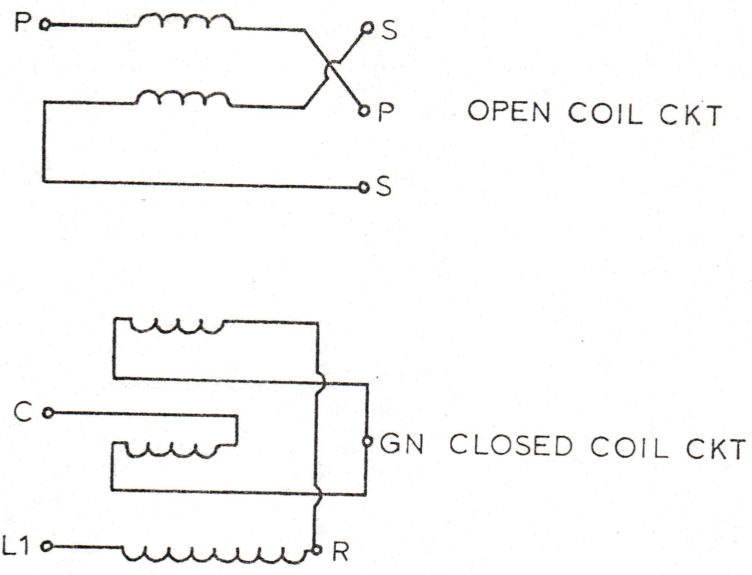


Figure 3-7. Open and closed induction coil circuits.

to be induced in the secondary coil. A common coil encountered in telephone sets is the WECo Number 101-A, employed in common-battery, anti-sidetone circuits. In these anti-sidetone circuits a tertiary coil is added. This cancels out the effect of the current appearing in the primary coil appearing also in the secondary coil, thus removing sidetone noise.

TELEPHONE CAPACITORS

Capacitors permit the passage of alternating current but open the circuit to direct current. They are used to vary the impedance of a circuit, depending upon the frequency being passed. When a capacitor is inserted in a circuit the impedance of the circuit varies inversely with the frequency. Since voice currents transmitted over telephone circuits ordinarily vary between 200 and 2,700 Hz and ringing currents ordinarily 20 Hz, it should be observed that the capacitor offers nominally higher impedance to the ringing circuit than it does to the voice frequency currents.

RINGERS

Ringers are signaling devices which produce sound to alert the subscriber. They are made of two coils of fine, insulated copper wire mounted on soft-iron cores together with a permanent magnet, an armature, a biasing spring, gongs and a mounting frame. (Note illustration in Figure 3-8.) When current flows through a coil, the coil has magnetic polarity which is dependent upon the direction of current flow. The coils of the ringer are wound so that the armature end of both coils appears as the north pole. The armature is positioned in the permanent magnet's field so that its center (fulcrum) is south pole, with a north pole on each end. When ringing current is flowed in the ringer coils the poles of the coils are constantly changed from north to south and back again. This is because ringing current is a-c (superimposed on d-c) and the ends of the armature, being

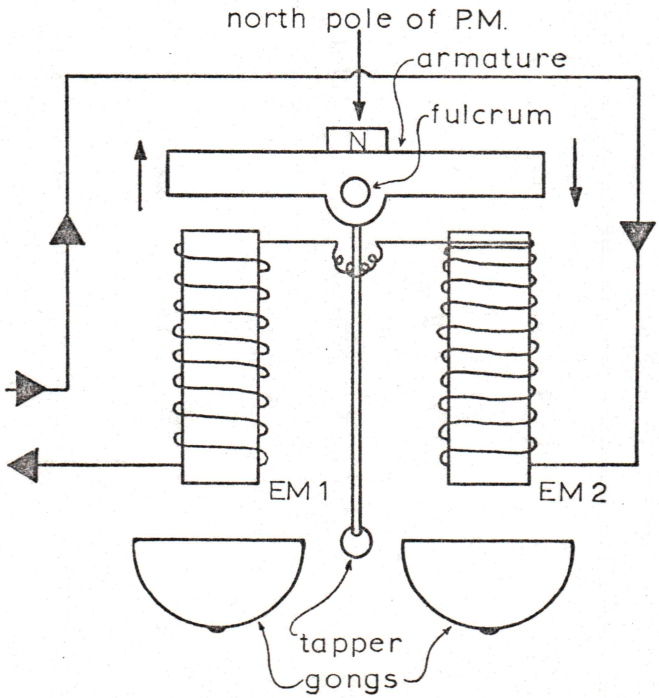


Figure 3-8. Telephone ringer circuit.

permanent north poles, are alternately repelled and attracted by the ringer's coil poles. Since the tapper is attached to the armature, ringing of the gongs results. A small spring, the biasing spring, holds the armature in one direction when it is at rest. It may be observed that WECo C-type ringers utilize only one coil, with the armature balanced between the pole pieces.

In order to prevent the ringer from tapping (bell taps) during short current surges when the circuit is broken by hanging up the handset or during dialing, the bell coils are "poled" or connected in a way that the surge of current stresses the armature with the pull of the biasing spring, not against it.

DIALS

The dial is a mechanical, spring-wound device which is designed to open and close a circuit at regular intervals. (Note Figure 3-9.) In normal, modern, automatic dial exchanges this interval varies at about 10 to 20 pulses per second. Dials are constructed so that they short the transmitter circuit during the process of dialing, although the WECo number 7 dial shorts the receiver during dialing, rather than opening it. Alternately opening and closing the circuit by the sequence and speed of the dial pulse openings operate banks of switching relays in the dial central office. By this action, circuits are made or "set up" to enable the calling part to be connected with the called party.

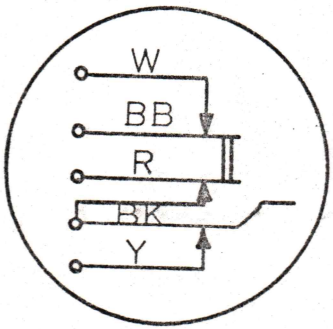


Figure 3-9. Typical dial switch detail.

Dials permit adjustments to be made so that their speed may be altered to conform with circuit requirements.

PLUNGER SWITCHES

The plunger switch, or hook switch as it has been called, is a device that opens the telephone circuit when it is not in use. The weight of the handset depresses two plungers that push against springs to open the circuit. (See Figure 3-10.)

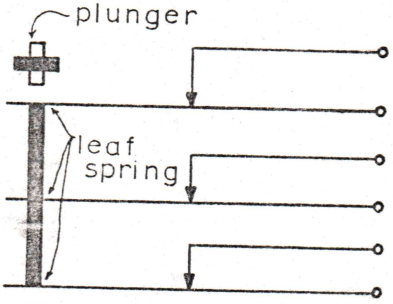


Figure 3-10. Typical plunger switch (hook-switch) detail.

The plungers are mounted in the cradle of the telephone set, in the area in which the handset is placed at rest. Note that the WECo 300 Series telephones have two plungers actuating springs, while the WECo 500 Series telephones utilize only one of the plungers to actuate the switching. Lifting the handset closes the switch contacts and automatically signals the operator on manual switchboards or causes the dial tone in automatic dial systems. Another type of hook switch operates when a separate receiver is lifted from the hook switch which also serves as a support for the receiver when the circuit is open. The principle of operation is the same as that of the plunger switch.

Three typical telephone instrument circuits are shown in schematic form to illustrate the normal use of some of the components mentioned. Depicted are the Automatic Electric Company's Number 40 anti-sidetone Monophone (see Fig. 3-11), the WECo Series 300 (see Fig. 3-12), and the WECo 500 Series instruments (see Fig. 3-13).

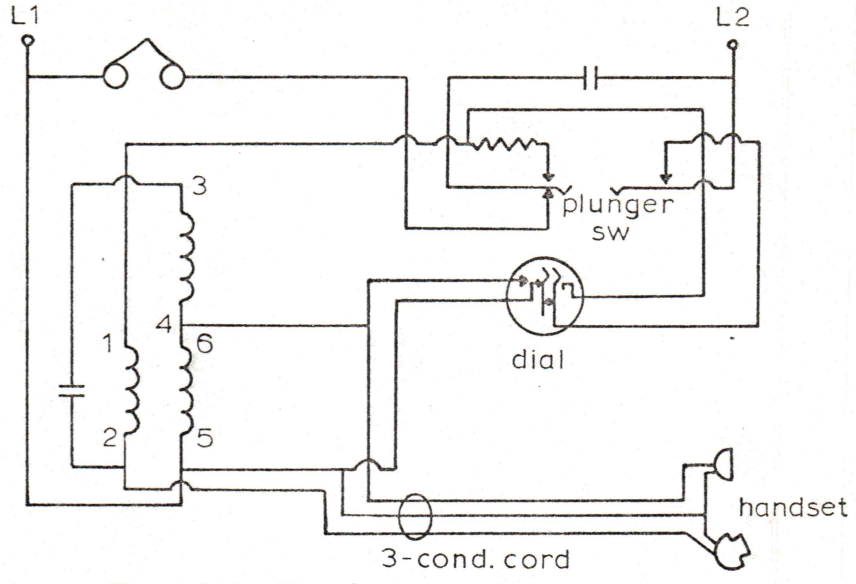


Figure 3-11. Typical automatic electric company subset.

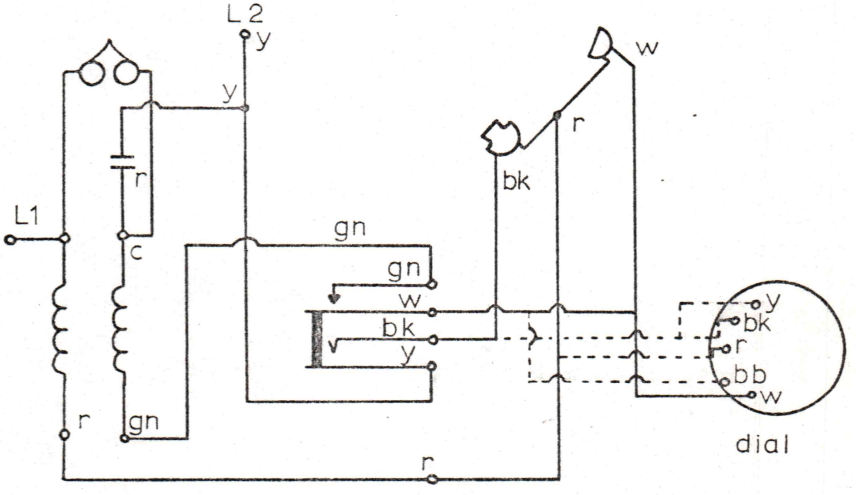


Figure 3-12. Typical W.E. Company subset (300 series).

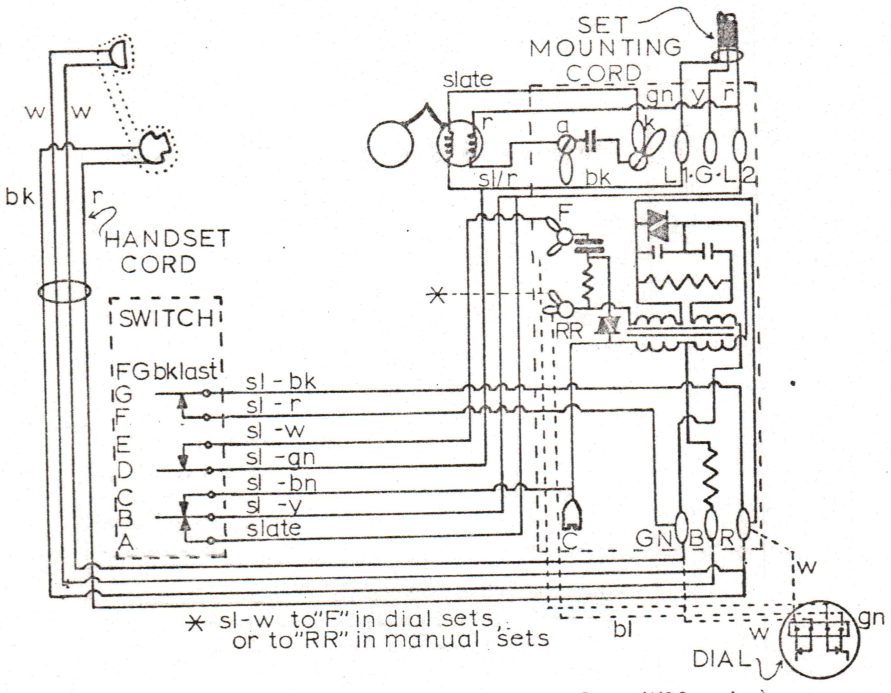


Figure 3-13. Typical W.E. Company subset (500 series).

SWITCHING SYSTEMS

If each telephone in a city were connected to every other telephone in the city there would be no need of remote switching systems. Consider, however, in a city of 100,000 telephone subscribers, it would be necessary to make 100,000 separate connections to each telephone instrument! Switching systems may be manual or automatic and will contain elements of both in most domestic and foreign exchanges. Manual switchboards are the main equipment used in nonautomatic exchanges and consist of circuits whereby any telephone line entering the switchboard may be patched to any other telephone line entering the board. This cross-connecting is performed by an attendant or operator who monitors the circuit until the calling subscriber reaches the called party.

The operator is signaled by a lamp or by audible means, whenever a party lifts a receiver and closes the circuit or when either

party hangs up and opens the circuit. It should be remembered that accidentally shorting both sides of the line on a manual exchange circuit will result in the signaling (and subsequent alerting) of the operator, while in an automatic exchange the same shorting will ordinarily not arouse human curiosity as to the origin of the disturbance, since only a dial tone will result (providing, of course, that the line is not specially monitored). Every telephone line is sent to the telephone central office and connected to jack terminals in the switchboard. In large-capacity boards some individual lines have more than one jack, so that they may be serviced by several operators.

We will trace a telephone call through its circuits in order to gain an idea of the functions of a manual switching system. The caller signals the operator by lifting the receiver in common-battery systems or in local-battery systems by turning the handle of a hand crank generator attached to the telephone set, before lifting the handset from the hook switch. This activity causes a particular shutter to fall in view of the operator which informs her that a caller desires to place a call and also which subscriber is calling. This shutter, or drop, is located directly above the jack with which it is bridged. As soon as the operator observes the drop that has fallen she plugs in her answering plug, throws her ringing-listening key to the ringing position and thus signals the called party who answers the telephone call. The operator also has facilities for ringing back the caller in the event that he hangs up by mistake or if he hangs up while awaiting placement of a long-distance call.

Machine switching or automatic dial telephone systems establish communications between telephone instruments without the assistance of an operator. This type of operation is also connected into manual boards so that human operators can give assistance in placing calls and furnish information. Most private branch exchange (PBX) systems are of the manual type and are connected by outside lines into the existing automatic exchanges. Certain private automatic exchanges (PAX) will be found in operation, utilizing the same general principles as herein described. Automatic dial telephone systems include such basic types of equipment as the step-by-step switching system, the

crossbar and the multiple-crossbar methods. Late circuits in the United States of America employ a circuit using the number 5 crossbar system. For the sake of simplicity, and due to its wide international usage, the step-by-step dialing system will be described. Developed by an American schoolteacher, Almon B. Strowger, in 1889, the Strowger step-by-step machine switching system forms the basis upon which most of the world's dial exchanges have been developed.

Telephone lines travel to a central office in which all lines serving a particular area are connected. This central office contains switching equipment, power and testing instruments. Most step-by-step dial centrals involve a two-wire 48-volt common-battery, fully automatic system, although 6, 12, 24 and sometimes 60-volt systems may be encountered. The two-wire system is one in which only two conductors go between the central office and the telephone instrument to which it is connected. Ordinarily this consists of two separate wires, known as a metallic return. Single-wire earth returns may be found in use, especially by military forces in the field. This pair of wires may be a twisted-pair, two separate copper wires on insulators or they may be enclosed in a multipair cable. A common source of d-c power is provided from storage batteries in the central office to operate the switching equipment and to power the individual telephone instruments. This power, in the United States, generally varies from 46 to 52 volts d-c and may be in the vicinity of 24 volts d-c in some exchanges. Equipment found in the central office includes connectors, linefinders, selectors, two-way repeaters (amplifiers), protectors and special service lines such as fire, holdup and burglar alarms, and TV and broadcast lines. Also found are banks of switches and relays mounted in large frames. These frames are comprised of main distributing frames (MDF), combined distributing frames (CDF), trunk intermediate distributing frames (TIDF) and selector distributing terminal assemblies (Selector DTA). In addition, service arrangements for operator assistance, testing facilities (Test Desk), monitoring, observing and recording equipment are provided.

Telephone dial revolutions, in step-by-step systems, transmit

the pulses directly to the switching equipment, which is in contrast to the type of system wherein dial pulses are "added" and stored in a switch for later sequencing of the called number. Dial pulses consist of interruptions of the line current due to the making and breaking of the dial pulse springs in the telephone dial. Dial pulses in the step-by-step system are called the "pulse train"; they transmit a connection, one step at a time, for each number dialed by the subscriber. These pulses are transmitted through stepping switches which make the connections all the way through the telephone system by movement of their contacting arms (also known as wipers) one step at a time. Subscriber's dialing moves the contacting arms by dial-pulse actuated electromagnets and results in the automatic switching to the called number.

Automatic equipment in dial central offices is designed to perform certain additional tasks. Among them are connecting and disconnecting both sides of the circuit (calling and called) when the conversation is terminated; ringing the called telephone if it is not in use; transmitting a busy-tone signal if a called line is in use (busy); distributing calling lines to interoffice trunks and further to called numbers in remote central offices; and supplying automatic trunk-hunting to any particular member of a group of private branch exchange (PBX) lines.

TRUNKS

Trunk circuits are lines connecting switchboards or switching systems to other switchboards. These trunk circuits between two switchboards serve a variety of purposes. They are a means of initiating incoming and outgoing connections to common-battery or dial system boards and provide a method of signaling the operator of an incoming call from another switchboard. They also provide for busy signals on multiple jacks and for a way to open the signal circuit when an incoming call is completed. In addition, supervision of the local circuit by the distant operator is provided, as may the employment of repeaters in certain cases. Trunk circuits may be automatic trunks, whereby the distant end is signaled without ringing (by d-c) or they may be provided

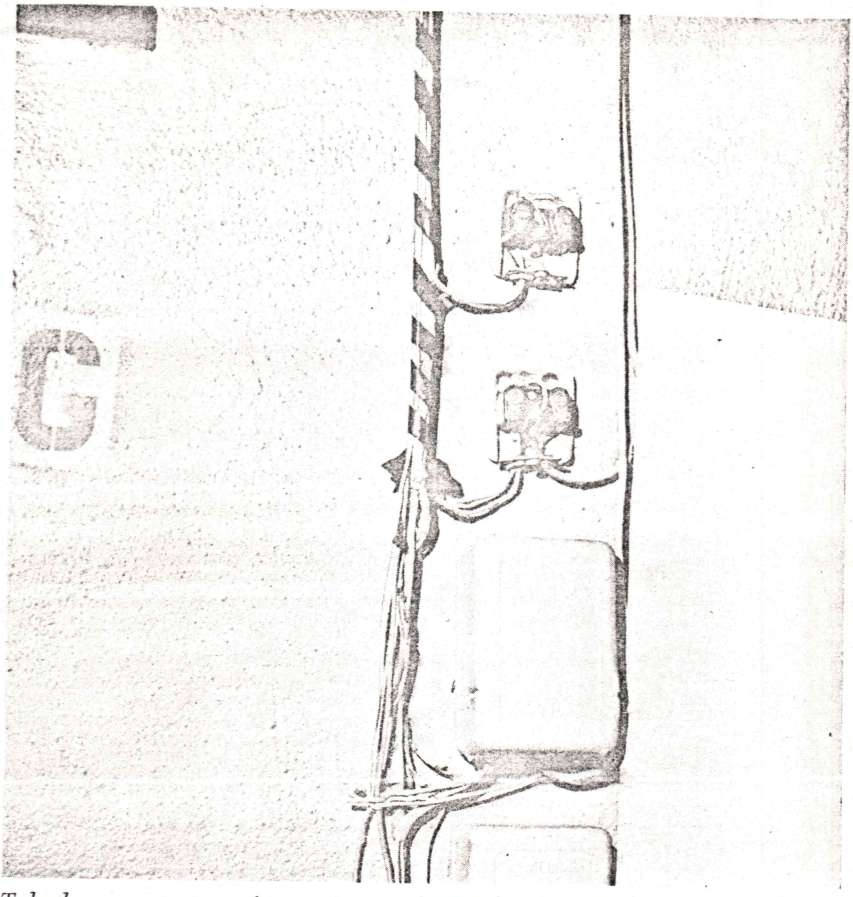
as ring-down trunks whereby ringing current is supplied to signal the remote board (by a-c). A one-way trunk has a signal at one end only and is known as an outgoing trunk if only the jack appears at that switchboard, with the signal located elsewhere. All sorts of combinations of these basic types are in wide use. Among these are found: automatic one-way, ring-down one-way, automatic or ring-down both ways, and ring-down one way and automatic the other.

MONITORING AND RECORDING

Provision is made in central office locations for monitoring and recording of telephone conversations. Depending upon the size of the central and the projected work to be done, the equipment may be very extensive. Telephone companies have serious penalties for employees found monitoring subscribers' lines without authorization. It is fairly well known, however, that switchmen and framemen amuse themselves during evening hours by listening to the lines which have been found to bear the most interesting traffic. At certain times, under the supervision of the office of the Chief Special Agent, particular lines are monitored in the central, very "safe," surroundings.

PROTECTORS

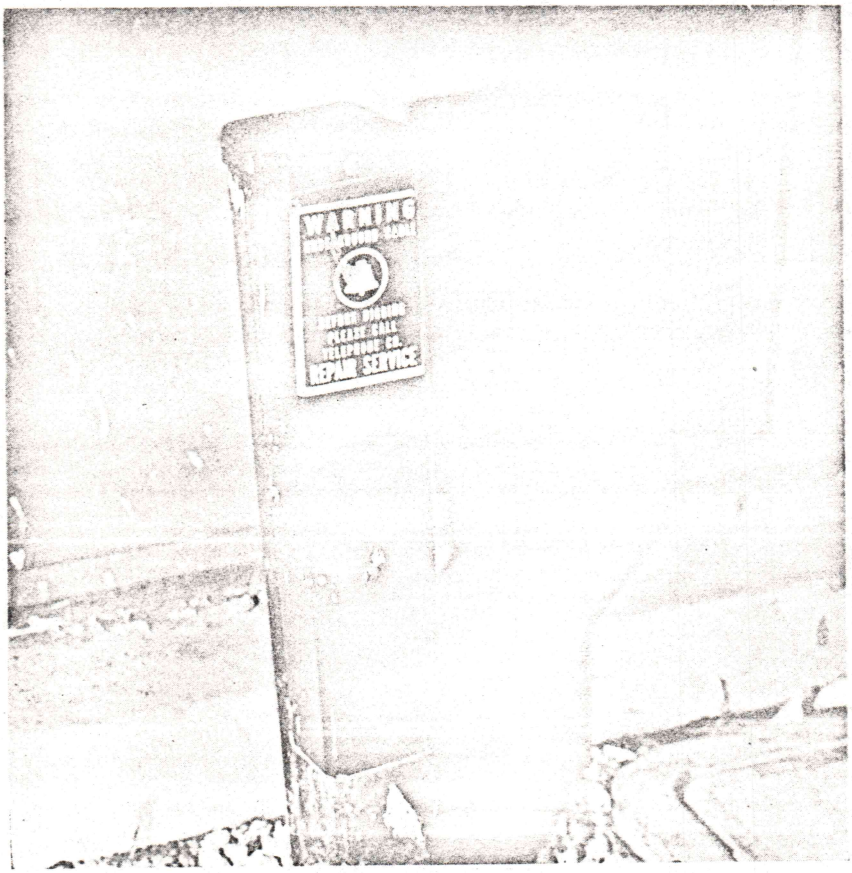
Safety devices, called protectors, are employed to protect telephone stations and central office equipment from damage due to electrical storms or accidental shorting of the plant to foreign voltage potentials. These protectors, which may take the form of fuses or carbon blocks, are usually mounted in metal boxes called protector boxes. Common types are the WECo 98A, the WECo 106C and the WECo 111A protectors. The two protectors listed first are usually found in the WECo 93C protector mounting, while the 111A protector is found in the WECo 305A mounting. These protectors are the ones most often encountered in the subscriber's premises. They are usually found in the basement or on outside residence or garage walls.



Telephone protectors of two varieties (WECo 93C and 104) mounted on the rear wall of a business. The covers of the 305A protector boxes have been removed and discarded by someone unknown. The sloppy wiring is typical of this kind of installation.

CABLE AND WIRE

Cable may be defined as a quantity of copper wires enclosed in a sheath or covering. A telephone circuit is known as a "line" when it is carried over two separate conductors, but when those conductors are enclosed with other conductors in a cable, they are termed a "pair." Cables are designated by the number of conductors and their thickness, as 16-pair, 19-gauge cable. This



Telephone protector in a post mount associated with underground service to apartments and condominium units in certain areas.

cable is rolled on reels varying in length from 500 feet to 2,000 feet and are shipped to supply centers where they are transported to the desired location and strung up or placed underground, by pole line construction workers. Later, splicers and their helpers arrive and splice these cables together.

Below will be found a description of the common types of cable and wire types, along with brief identifying features:

Cable

Cable NH, 16-gauge. Used in exchange trunk plant; 26 to 152 pairs, lead sheath, paper-tape insulated.

Cable ENB, 19-gauge. Used in subscriber and exchange trunk plant and in certain toll plants; 6 to 455 pairs, lead sheath, wood-pulp insulated.

Cable FNBL, 19-gauge. Used in subscriber and exchange trunk plant and in certain toll plants; 6 to 455 pairs, lead sheath, paper-tape insulated.

Cable GNBL, 19-gauge. Used in subscriber and exchange trunk plant and in certain toll plants; 6 to 303 pairs, lead sheath, paper-tape insulated.

Cable DSA, 22-gauge. Used in subscriber and exchange area cables, and also in subscriber and exchange trunk plant; 11 to 909 pairs, lead sheath, wood-pulp insulated.

Cable DSM, 24-gauge. Used in subscriber and exchange trunk plant; 11 to 1,515 pairs, lead sheath, wood-pulp insulated.

Cable BST, 26-gauge. Used in subscriber and exchange trunk plant; 11 to 2,121 pairs, lead sheath, wood-pulp insulated.

Note: Other types come shielded with aluminum or steel tape, with soldered seams, covered with a polyethylene jacket. Some types, designed for aerial or underground conduit construction, have conductors individually insulated with polyethylene.

Wire

Drop wire. Used for connecting telephone station protectors with terminal boxes and for short runs between poles to larger terminal boxes. Comes in twisted pair, parallel reinforced, parallel neoprene, parallel dumbbell and hard copper, underground burial twisted pair. It bears two conductors, is insulated with black neoprene and comes in 1,000-feet rolls. Wire gauge may be either 16 or 18 (underground types may also be found in 12-gauge).

Interior wire. Used for interior connection of telephone station apparatus. Comes in twisted pair, triplex or quad, insulated with vinyl plastic. Two-conductor may be colored ivory and brown, red and black, or red and white. Triplex may be red, white and yellow *or* red, black and yellow. Quad may be found in red, green, yellow and black. Wire gauge may be 19 or 22.

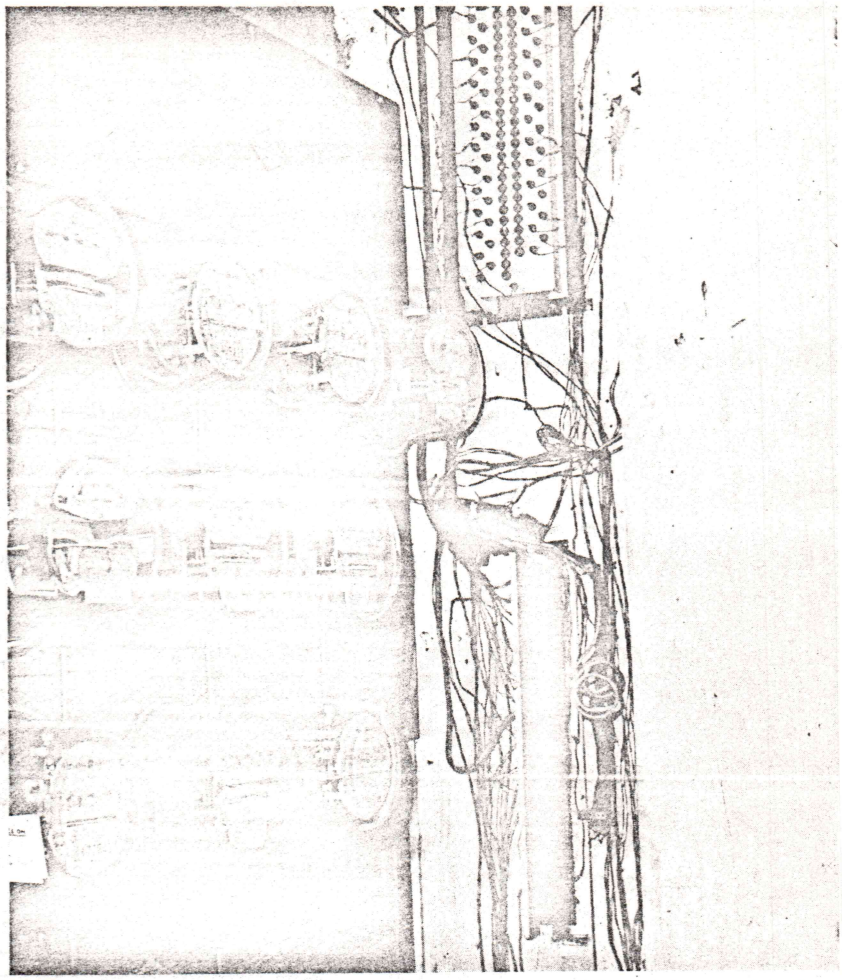
Station wire (inside and outside). Used for interior connection of telephone station apparatus and PBX systems. Inside type is insulated with vinyl plastic, while outside type is neoprene insulated. May be obtained in two, three or four conductor types. Inside wire jacket may be beige, brown or ivory in color. Conductors may be red and green; red, green and yellow; or red, green, yellow and black. Outside station wire has a brown or beige jacket and the same color conductor insulation. The wire gauge is 22.

Ground wire. Used to ground telephone apparatus and protectors to earth ground or water pipes. Comes in 10, 12 or 14-gauge as a single copper conductor with black, brown, white, or beige vinyl plastic insulation.

TELEPHONE PLANT–SUBSCRIBER TO CENTRAL OFFICE

The typical subscriber's telephone set is connected by a set mounting cord to a subset or directly to a connector block at the baseboard. If a subset is used, it is connected directly to the protector box with interior wire. Generally, inside or interior station wire of the three-conductor type is used between the connector block and the protector block. The red and the green conductors are for L1 and L2 (tip and ring), and the yellow conductor is used for grounding. At the protector box, the red and the green station wires are connected to either a fused or a fuseless protector, while the yellow conductor is connected to a binding post, which is in turn connected to a cold water pipe or an earth ground rod by ground wire. The other sides of the fused or fuseless protector, which is often located in the basement or on the outside wall of the house, are connected to the two conductors of a length of drop wire which is run through screw-eyes and clamps up the side of the house wall and to the nearest utility pole by the shortest aerial route. At the pole, the drop wire enters a terminal box where it is spliced into a cable traveling toward the central office.

The subscriber's pair may make several appearances (appear at exposed binding posts) in larger terminal boxes before it finally enters a subsidiary duct and becomes subterranean cable. It would then be carried through one or several underground cable vaults (manholes) and enter the central office. Here the cable is fed through a series of protectors again and into the main distributing frame as an individual pair once more. Tie cables and jumpers connect the pair to the line and cut-off relay rack and the intermediate distributing frame. Switchboard cables carry the pair to the central office boards, usually located in another part of the building. (Observe the illustration in Figure 3-14, for the graphic view of the typical subscriber's telephone circuit.) This summary of the principles of telephone systems, coupled



Twenty-five pair telephone terminal boards mounted on the inside of an electrical service cabinet located on the outside wall of an apartment house. Observe the chaotic wiring which is often seen in these cases.

with a study of the telephone glossary, should provide the audio specialist with a working knowledge of general telephone operations.

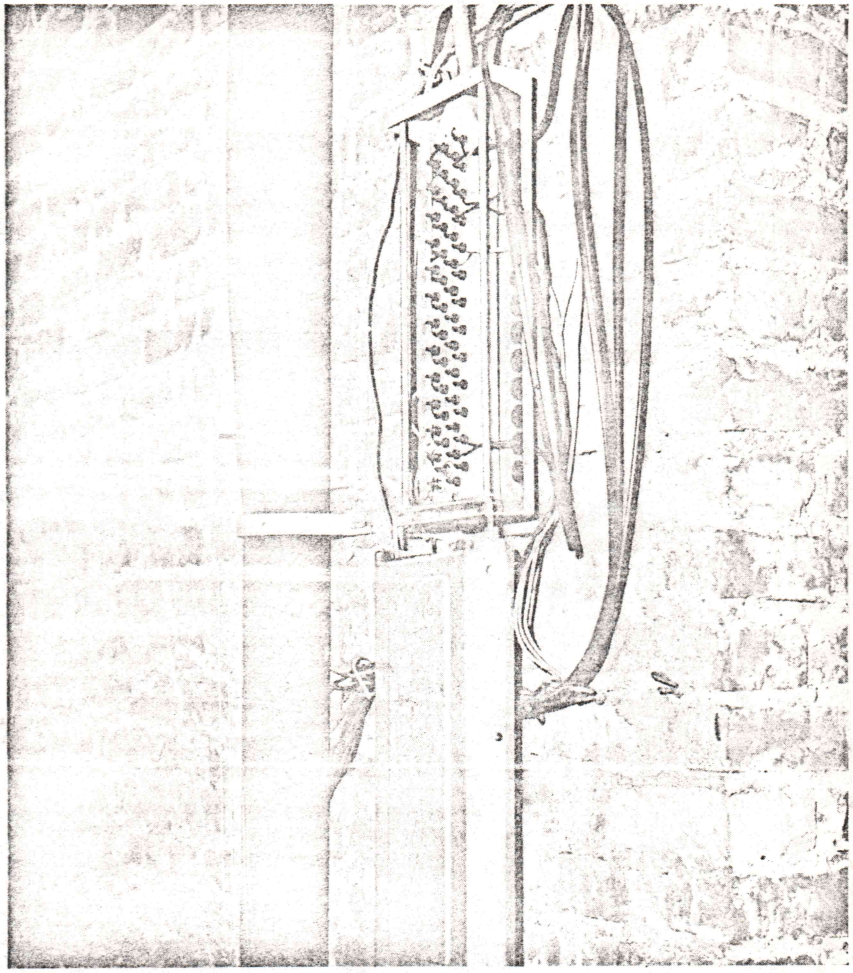
FOREIGN TELEPHONE SYSTEMS

The audio surveillance technician may find himself operating in countries other than his own and, consequently, will encounter a variety of telephone systems, ranging from crude to sophisti-

Telephone terminated cabinet located in the open basement parking area of an apartment house. Observe the open terminal board which has been interposed between the cabinet and the interior station wiring.

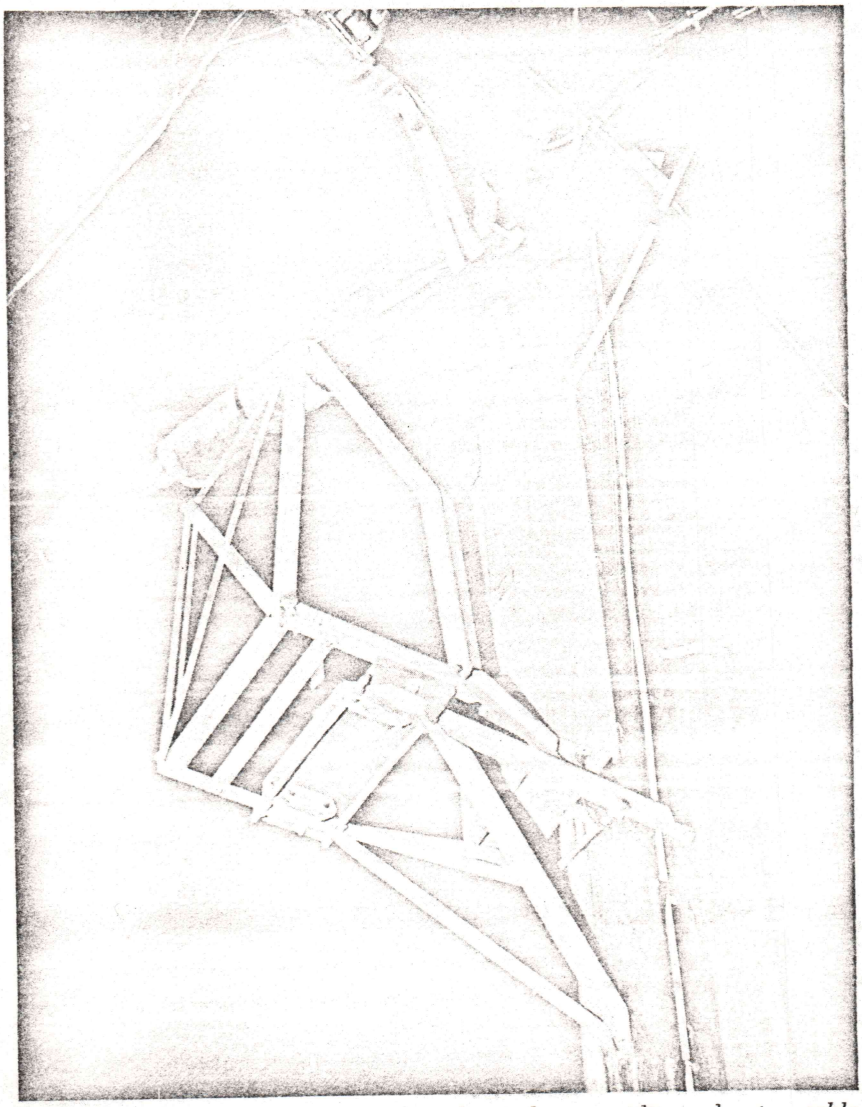
cated, differing to various degrees from the Western Electric to Kellogg to Automatic Electric Company equipments used predominantly in the United States. If security measures in effect permit the use of reliable indigenous personnel, this approach may prove to be the best advised unless operating personnel are completely familiar with such foreign system and the language, customs, dress, protocol and technical procedure of the visited country.

There are many varieties of switching equipment in use in

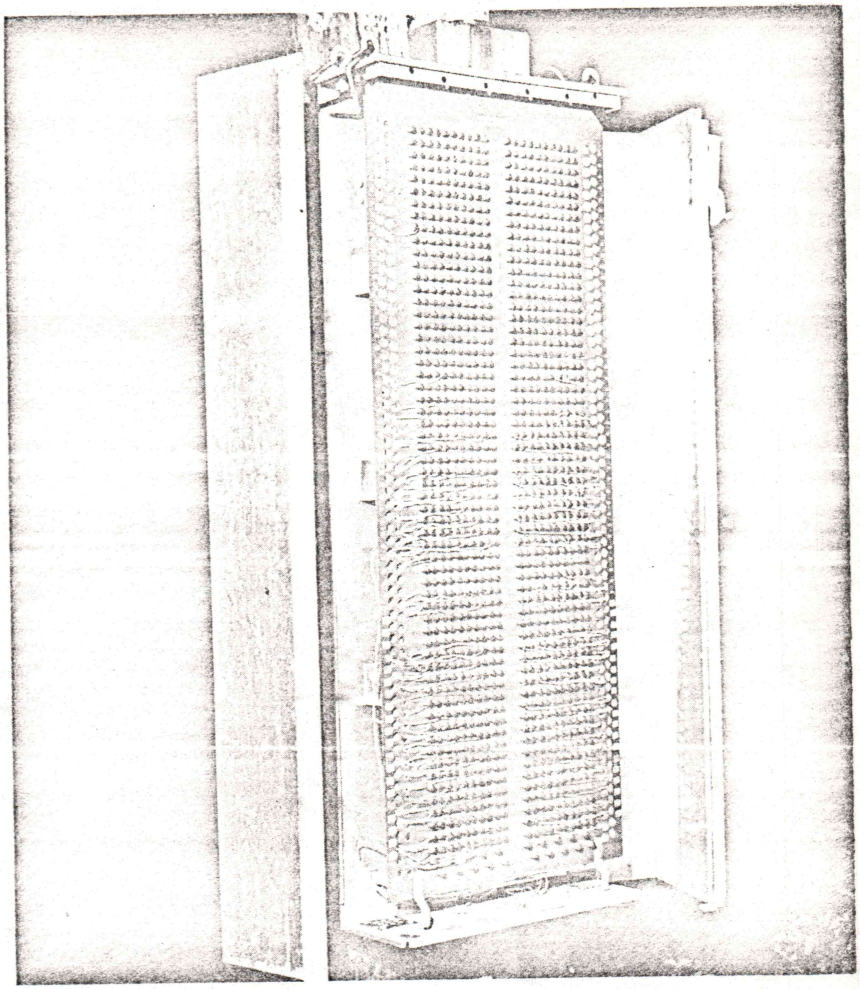


Twenty-five pair terminal box mounted on the rear wall of an office building.

the local central offices of various foreign countries, and any number of obsolete, special or improvised switching systems will be seen. Sometimes the use of telephone components and equipment drawn one way or another from the local telephone executive may be advisable since there should be no question as to the workability of this equipment with the other existing equipment. Problems, however, may arise due to unfamiliarity with the equipment and a lack of spare parts stores.



Telephone "B" box, or bridging point, located on a utility pole at a cable crossing.



Six-hundred pair terminal box, also known as a bridge-head, bridging point or "B" Box. This point serves an entire neighborhood.

Foreign central offices may be characterized as having been engineered "closely," whether from the traffic capacity or extra-terminal standpoint. Many of them have unreliable power supplies, low capacity for many multiple calls, timed cut-off features and unusual interposition trunking, linking nonmultiple switchboards, thereby resulting in slow completion, poor transmission quality and false disconnects. Further problems arise with equip-

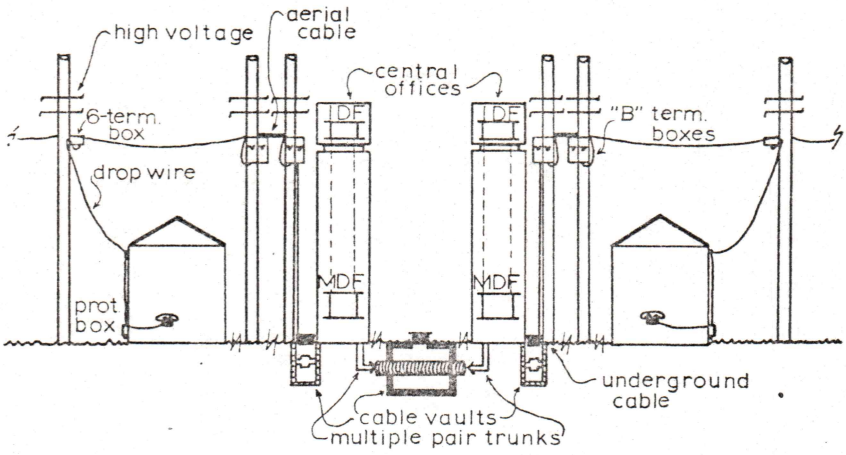


Figure 3-14. Typical telephone system plant.

ment that is inadequate and poor to begin with, made even worse by little or no maintenance because of a shortage of spare parts and trained personnel.

In planning an interconnection, the operative must take into consideration the type of switching system—whether magneto, common-battery manual, central battery signaling or all-dial—and the condition, voltage and resistance of the transmission line in general.

Transmission Line Problems

One of the most widespread differences encountered will be that of the use of telephones with high-resistance transmitters, along with associated high-resistance talking battery in the central offices. The standard Ericsson power-driven dial system uses telephone transmitters with a resistance of 200 ohms, along with a central office talking battery power supply of 24 volts through a 400-400 ohm coil. Most standard American telephone transmitters are of the low-resistance type and would operate at greatly reduced efficiency with such a battery circuit.

Another Ericsson power-driven dial system type of switching system employs a 48-volt battery through an 800-800 ohm supply, although it is also seen using 50 volts through 200-200 ohms as an adaptation for the use of low-resistance transmitters. In some

cases the central office battery circuit is boosted to 60 volts to compensate for high-resistance battery supply although many low-resistance transmitters will continue to furnish inadequate service under these conditions.

Magneto Offices

In local battery (LB) or magneto offices, which are still in widespread use in outlying areas, irregular switching systems are usually found. Special problems include low-resistance (100-ohm) line signals, loops capable of no more than 1,000 ohms, all or part of the lines set for party-line service with (in some cases) a secrecy signaling circuit for the subscriber to call the central office. These station magnetos are normally circuited across the line, while central office signaling is controlled by a station key while ringing. In some cases 50-Hz ringing current is found, while in others d-c bells and signals appear at the stations and on PBX trunk lines.

Central Battery Signaling Offices

In some of these central battery signaling (CBS) switchboards the line signal is actuated on metallic return by the station loop while the cord supervisory signal is effected by a ground connection through a low-resistance station ringer which circuits, when the switch hook is depressed, with one side of the line. It is possible to identify this signaling arrangement by testing for a potential on the subscriber's line when it is not in use. When the line is bridged and the operator comes on the line, the potential is no longer on the line but rather appears from both sides to ground. Here, also, 50-Hz ringing current may be found.

Common-Battery Manual Offices

Fewer problems exist with the common-battery (CB) circuit, and it is compatible with most American equipment. Exception again must be made for those boards having high-resistance transmitter battery in the cord circuits and those in which the high-resistance transmitter battery is circuited by line relays. Message rate registers are often found in the CB office, and some localities employ 50-Hz ringing current.

Dial Offices

Modern dial centrals generally operate with satisfactory supervision, pulsing, and ringing circuits and are often compatible with American equipment—with the exception of the too-rapid American commercial dials (20 pulses per second). Most foreign dials operate from 9.5 to 10.5 pulses per second (which includes a tolerance of ± 5%). Dialing pulses may cause problems, such as wrong numbers, when operated at the end of a long loop and the pulses fall as low as 8 per second. Any dialing equipment used should be reset, in these cases, to dial an average of 10 pulses per second. The WECo 51A, or other close-tolerance dial, will prove suitable here unless local equipment can be discreetly procured.

Dial Number Plate Variations

Dial number practices vary considerably all over the world and in some localities vary between areas of the same country. They differ to a great degree from American dial markings. Below is shown a chart containing some ordinary foreign dial number plate variations:

1. *Copenhagen, Denmark—Metropolitan Areas*

Numbers:	1	2	3	4	5	6	7	8	9	0
Letters:	Central	ABD	EFG	HIK	LMN	OPR	STU	VXY	AEø	Hjaelp

2. *Denmark—Rural*

Numbers:	1	2	3	4	5	6	7	8	9	0
Letters:	A	B						X	Y	Central

3. *England—Metropolitan Areas*

Numbers:	1	2	3	4	5	6	7	8	9	0
Letters:		ABC	DEF	GHI	JKL	MN	PRS	TUV	WXY	0

4. *France—Metropolitan Areas*

Numbers:	15	2	3	4	5	6	7	8	9	0
Letters:		ABC	DEF	GHI	JKL	MN	PRS	TUX	WXY	OQ

5. *Germany, Austria (Certain Localities)*

Numbers:	1	2	3	4	5	6	7	8	9	0
Letters:	A	B	C	D	E	F	G	H	J	K

American dials may be re-lettered for the area involved or ordered initially with numbers only and the letters added under the dial escutcheon.

In some foreign areas, toll and local calls are often cut off automatically after a preset interval of from four to twelve minutes has elapsed. This process is known as "time-releasing"

and should be understood by operating personnel to avoid panic situations.

Central battery signaling (CBS), using switchboards capable of handling between 10 and 1,000 lines, is waning in its use but is still found in England and France and all their possessions.

Common-battery (CB) switchboards, made by all the manufacturers, are to be found the world over.

Full dial service is provided by register (sender) systems using rotary power-driven equipment and may be found all over Europe and South America, in addition to certain locations in China. It is not used in Germany, England or Sweden. Manufacture is by affiliates of the International Standard Electric Corporation, with the largest suppliers being the Bell Telephone Manufacturing Company of Antwerp and Le Material Telephonique de Paris (LMT).

The *Ericsson power-driven dial system* is a register (sender) system providing full dial service, manufactured by branches of the L.M. Ericsson Company, Head Office, Stockholm. Equipment of this type has been extensively provided to the government of the Soviet Union. The equipment may be found in Europe, Asia and South America. It is not used to any degree in England or Germany.

Step-by-step dial systems, also known as the *Strowger Automatic System*, are full dial service equipments with the key feature being the director-type of step-by-step switching where registers (senders) are not used. It is the most widely used system in all the countries of the world, offices varying between 100- and 10,000-line units. It is found widely in metropolitan England and in Havana, Cuba. Principal manufacturers include Automatic Electric Company, Chicago; Automatic Telephone Manufacturing Company, England; Siemens-Halske Company, Germany; and certain branches of International Standard Electric Corporation.

The *Thomson-Houston R-6 Dial System* is a full dial service system employing a magnet-driven rotary selector in each switching stage where the dial pulses do not directly follow the station dial pulses as they do in step-by-step switching systems. Found generally in France and in the French colonies, it has been seen

around Lille, in suburban Paris and in French North Africa. The offices vary, generally, between 100 and 7,000 lines. The manufacturer was the Thomson-Houston Company of Paris; it is still being made by branches of the International Standard Electric Corporation of which the primary supplier is Le Materiel Telephonique de Paris (LMT).

Another magnetic-operated selector switch is the *Hasler 121 point selector* which enables full dial service through the use of registers (senders) which further control the switches. It resembles the Ericsson selector but has only 121 points as opposed to the Ericsson's 500 points and is magnet-operated rather than power-driven. It handles between 100 and 10,000 lines. The system is manufactured by Hasler, S.A., Berne, Switzerland, and is there widely used.

Using a distinctive vertical drop selector, the *Merk Fallwaehler (drop selector) Dial System* provides full dial service with conventional dial telephone equipment. It is capable of handling between 100 and 6,000 lines. The system is in use in many government offices in Germany and will be found in Japan and in the former Italian colonies in North Africa. The manufacturer was Telefonbau u. Normalzeit A.G., Frankfort-am-Main.

In the *Demiautomatic System* (D System), the service offered is a combination of manual and dial service whereby the caller dials the central office prefix of the called number and is connected to a manual board operator to whom he states the last four numerical digits. The manual board operator then plugs his line into the line multiple jack of the called number. This system is an interim system for use when in the process of converting from manual boards to all-dial operation. It may be converted to the full rotary system. It was manufactured by the Copenhagen subsidiary of International Standard Electric Corporation and has been used throughout Denmark.

Semiautomatic dial systems (automanual systems), consisting of remote stations in a building served by a switchboard within the same building, where the operator dials the number for the caller, are found throughout Europe with the exception of Germany. Normally the boards may handle up to 50 lines per

operator, and the systems vary in lines served between 200 and 2,000 to 3,000. They have been produced by a large number of manufacturers.

All-relay dial systems, providing full dial service using conventional telephone apparatus, have for many years been increasing in usage throughout Europe. More common in Europe, they are encountered lately in greater numbers elsewhere in the world. It is common to see these systems utilizing between 10 and 100 lines, although they are capable of handling up to several thousand lines. All of the major manufacturers of dial equipment may be expected to supply these systems.

Other minor systems, such as the *Magneto Remote Control Dial System and the Common Battery Remote Control Dial System,* are scattered in dwindling amounts throughout Europe, with the exception of Germany, and are rarely seen today. They have been manufactured by the Automatic Electric Company, Chicago; Automatic Telephone Manufacturing Company, England; and for export only, by Siemens-Halske, Germany.

In the American crossbar system, the dial pulses transmitted by the subscriber's telephone dial are sent to a "mechanical operator" (sender) which converts these pulses to secondary electrical impulses to activate the required switches to initiate the through connection. The crossbar system may be considered, in effect, an all-relay system. Connections go through different switching frames including the line-link frame, which serves as a line-finder for the calling central and a final selector at the called central.

In contrast to the American crossbar system, the *Swedish crossbar system* is designed so that all switches, except the line-finders, follow the dial pulses in making the line selection, rather than as in the standard American crossbar system where the control is common. The Swedish system uses a crossbar switch as line-finders, selectors and connectors, providing full dial service employing standard dial telephones. Originally produced by Swedish government plants, the equipment has also been made by the L. M. Ericsson Company, Stockholm. These systems, which ordinarily vary between 20 and 90 lines, may be seen

widespread in the rural areas of Sweden, although several large line capacity offices exist in the larger urban areas of Sweden.

In contrast with the telephone systems encountered within the United States, those of the balance of the world may present some unique problems in telephone line observation practice. A basic understanding of the various systems in use, however, should prove helpful in solving some of the problems that always arise in surveillance electronics.

Chapter 4

RADIO SYSTEMS

SINCE MANY OF THE sound technician's assignments involve the use of radio transmitting and receiving devices, it is considered essential that he have at least a rudimentary understanding of the general principles of radio systems. In addition, the demands of rapid, flexible communications in the law enforcement and intelligence field place the additional burden of field maintenance on the shoulders of the sound specialist. Many times while on missions he will be called upon to perform emergency service to two-way radio instruments where their failure could cause serious effect on the accomplishment of the project. It should be remembered that United States' law provides transmitter adjustments be made only by persons licensed by the Federal Communications Commission to do so.

COMPONENTS OF TRANSMITTERS

Oscillators

The heart of both transmitters and superheterodyne receivers is the radio frequency oscillator circuit. Vacuum tubes and transistors may be caused to oscillate when the output circuit is coupled back to the input circuit in such a way that part of the voltage is sent to the grid of the tube, or base of the transistor, and amplified to a point where sustained oscillations are produced.

There must exist two conditions for this oscillation to occur. Feedback from plate-to-grid circuit or from collector-to-base (regenerative feedback) must occur in such a way as to reinforce the potential on the grid or base. This feedback must be of sufficient magnitude to overcome any losses in the tuned circuit. This feedback may be enhanced by capacitive, inductive or

resistive coupling. The frequency of the oscillations thus produced are dependent primarily on the values of the inductance and capacitance in the tuned circuit. The vacuum tube or the transistor itself does not oscillate but merely serves as an automatic valve which controls the flow of electrons into the oscillating tuned circuit. The frequency of the tuned circuit is determined by variations in the coil-capacitor tank circuit. The resonance of the tuned circuit is governed by the formula:

$$F = \frac{1}{2\pi \sqrt[2]{LC}}$$

where F = Hertz (approximate oscillating frequency)
L = Inductance in henrys
where C = Capacitance in farads

Oscillators may be of several types, the simplest of which is the tickler-coil oscillator. In this case the feedback is accomplished by means of inductive coupling between a small coil in the plate, or emitter circuit, and the coil in the plate, or base, circuit.

Another oscillator, which uses a split-winding coil, is called the Hartley oscillator. Part of the coil is in the grid, or base, circuit, while feedback is produced by the coupling between the other portion of the coil and the plate, or emitter, circuit.

The Colpitts oscillator is virtually the same circuit as the Hartley circuit but differs in that a pair of capacitors are used instead of the split-winding coil.

Tuned circuits are contained in both the grid and the plate circuits (or the base and the collector) by the tuned-plate tuned-grid oscillator.

Also utilized are electron-coupled oscillators wherein both the grid and the plate circuit contain tuned circuits, and the coupling is by the interelectrode electron stream. This type of oscillator combines the oscillator with a power amplifier in the same tube, whereas oscillators are usually designed merely to create the oscillations and the amplification of the signal is performed by a power amplifier circuit.

By the addition of a carefully tuned quartz crystal to the circuit of the oscillator, great stability of frequency is obtained. Only a small a-c signal need be applied to the crystal, at its

resonant frequency, in order to cause the crystal to vibrate at its own resonant frequency, further generating even larger voltages at the crystal's resonant frequency.

A crystal inserted in the grid circuit of a triode, along with a tuned circuit in the plate circuit, forms the familiar tuned-plate tuned-grid oscillator with exceptional frequency stability and higher level r-f output.

With the crystal-controlled Pierce oscillator, which requires no tuning circuit, the crystal is connected directly between plate and grid and the circuit takes on the electrical equivalence of the Colpitts oscillator. The feedback is here induced by the plate-to-filament and grid-to-filament capacitance of the tube. Transistor operation is similar, using interelectrode capacitance between base and emitter and between emitter and collector. Low r-f output characterizes this circuit.

Power Amplifiers

Should the oscillator be connected directly to an antenna some radiation of r-f energy will take place, but of a very weak nature. It becomes necessary to pass the oscillator's r-f waves through a tuned power amplifier before feeding the antenna. This power amplifier stage has a tuned input circuit (the oscillator-plate tank) and a tuned output circuit (the amplifier-plate tank) both tuned to the same frequency. In this way the r-f amplifier is similar to a tuned-plate tuned-grid oscillator. The r-f amplifier is coupled to the oscillator by d-c blocking capacitors, that pass the a-c r-f signal but prevent the flow of d-c, and r-f chokes that prevent the flow of r-f energy to ground.

Buffer Amplifiers

To overcome frequency instability in the oscillator, resulting from a varying load placed on it by power requirements of the r-f amplifier, a buffer amplifier is employed. It serves to isolate the oscillator from the r-f amplifier, without providing much r-f amplification.

Frequency Multipliers

Since there is a physical limit to the size of quartz crystals, there is a corresponding limit to the practical frequency of oscillation of such crystal oscillator circuits. With regard to high-

frequency operation, this problem is solved by the use of frequency multiplier circuits. This principle takes advantage of the generation of harmonics, or multiples, of the fundamental crystal frequency. The signal is purposely distorted, and the desired harmonic is selected by the use of further tuned circuits. Should the second harmonic frequency of a crystal be chosen, the circuit is termed a "frequency doubler"; if the third harmonic is employed, the circuit is called a "frequency tripler." Unwanted interfering or parasitic secondary oscillations sometimes occur and are suppressed by the use of resistors or r-f chokes in critical parts of the circuit. Slight changes in component values may also effect elimination of these parasitics, as may the careful control of wiring and parts placement.

Amplitude Modulation

If the voltage on the plate circuit of the r-f amplifier were varied, in consonance with audio frequencies, the r-f output of the transmitter would be raised at the same rate. The resulting product is called amplitude-modulated r-f. In contrast, continuous-wave transmitters result when the power to either the grid or the plate of the final r-f amplifier is interrupted by a radio key.

The necessary audio voltages are produced by feeding the weak microphone output to a speech amplifier which raises the voltage to a degree where it can be fed to the grid of an audio power amplifier (known as an audio modulator). The output of the modulator is then applied to the plate of the final r-f amplifier, which results in amplitude-modulated (A-M) voice r-f signals. Although plate modulation is the most widely used, other forms exist. These are known variously as grid, grid-bias, suppressor, screen-grid or cathode modulation.

Frequency Modulation

To eliminate noise and static impulses, which are combined with an incoming A-M signal, the principle of frequency modulation (F-M) was developed. Utilized here is a specially designed transmitter and receiver that respond only to frequency-modulated waves and reject amplitude-modulated waves. The

result is high-quality reception accompanied by almost no noise or static. F-M transmissions may be effected by the use of reactance-tube or Armstrong phase-modulation systems. In reactance-tube modulation, the r-f signal is modulated at the oscillator, while in the phase-modulation system the modulation takes place in a stage following the oscillator. The reactance-tube modulator also makes use of an additional crystal oscillator, a frequency converter and a discriminator stage. The phase-modulation system employs an r-f carrier amplifier, a combining network into which the output of the r-f carrier amplifier is fed along with that of the audio power amplifier, through a rectifier to the usual frequency multiplier stages.

COMPONENTS OF RECEIVERS

Basically, radio receivers consist of a radio-frequency detector, which recovers the modulation from the modulated r-f wave, and a series of audio-frequency amplifiers which multiply the audio signal to a level necessary to drive earphones or loudspeakers. One of the more simple receivers is the tuned-radio-frequency receiver. The t-r-f receiver employs a variable-frequency tuned circuit r-f amplifier ahead of the detector, for the purpose of selectively amplifying those r-f signals it is desired to receive. Regeneration, or feedback, is employed in the detector circuit and results in extreme sensitivity of the receiver. Due to the lower selectivity and sensitivity of tuned circuits operating above about 5 MHz, due to the lower Q value of these tuned circuits, these t-r-f receivers do not function well above that point. In their place, the superheterodyne receiver has received recognition for the consistent ability to operate satisfactorily on any frequency with constant selectivity and high sensitivity.

Superheterodyne Receivers

The superheterodyne (also known as the superhet) receiver contains a tunable r-f amplifier which feeds into a mixer stage, into which is shunted the output of a local oscillator stage. If the local oscillator, for example, is tuned to 41.550 MHz, while the r-f amplifier is tuned to 42,000 MHz, the mixer develops the

difference between these two frequencies, and a new frequency, the intermediate-frequency (i-f), results. It is the result of the heterodyning of these mixed signals which creates a new frequency—the difference between the two frequencies. In this case, the i-f would be 450 kHz, and it is coupled to the input of the i-f amplifier, which is tuned to receive the 450 kHz signal. The wave is then sent through a second r-f detector, tuned to 450 kHz, and any audio component is rectified to an audio varying d-c which is further altered to an audio frequency a-c through a resistance-capacitance coupling circuit. The audio frequency a-c is then fed to a series of audio amplifier stages which drive a loudspeaker.

Through the use of variable, signal-controlled, bias on the amplifier stages, an automatic volume control (AVC) circuit may be added. This prevents overloading by strong signals and underloading by weak signals, resulting in a more stable volume condition with reception of signals varying in strength. Also operating from the AVC voltage is a squelch circuit that quiets the receiver during periods of "no-signal" condition. As soon as a signal is received the squelch control is defeated and the amplifier responds normally. Also depending on the AVC voltage for operation is a signal strength measuring device called the S meter. It measures signal strength in arbitrary units called S units, 1 (weak) through 9 (strong), and depends upon the variation in bias of the AVC stage to indicate the strength of signals received.

Double-conversion Superheterodynes

More complicated versions of the superheterodyne are available; one of these is known as the double-conversion superheterodyne and utilizes two mixer, or converter, stages, operating at different i-f frequencies. Normally, an r-f gain control is provided in the r-f amplifier. The result is even better sensitivity and sharper selectivity.

F-M superheterodyne receivers are similar to A-M superheterodyne receivers, except for the addition of a limiter stage in place of the second i-f stage of the A-M unit and the substitution of a discriminator for the A-M superhet's detector stage.

The F-M receiver's tuned circuits are designed to pass a much wider band of frequencies than those of the A-M superhet. The limiter, which may be thought of as a special kind of i-f amplifier, serves to reject any A-M signals appearing at this stage, passing only F-M signals to the discriminator stage. The discriminator, which is a special kind of detector, interprets the frequency variations of the F-M r-f signal in terms of audio signals rather than amplitude variations as is done by the A-M detector stage. The receiver, from that point, operates similarly to an A-M receiver.

Frequency modulation offers several advantages over amplitude modulation. Among these are dramatic reduction in noise and static and more faithful reproduction of audio frequencies. For these reasons it is almost invariably chosen for electronic audio surveillance use.

COMPONENTS OF POWER SUPPLIES

All electronic equipment has a requirement for a source of electrical power. The source may be batteries or generators (primary power sources) or it may be devices capable of converting the outputs of these primary sources into levels and types of current required by specific electronic equipment. The devices that provide this converted power are referred to as power supplies.

Power supplies and certain primary power sources provide correct operating voltages and currents for electron-tube circuits, transistors, relays, d-c motors and other communications equipment. While a-c can be used for some heater and filament circuits, the power supply must be able to provide smooth, ripple-free, d-c to supply the grids, plates and screens of electron tubes and the operating source for transistor circuits. Ordinarily a-c voltages are rectified and filtered to provide this smooth d-c supply which keeps objectionable a-c hum out of the receiver output and to prevent carrier modulation by hum in transmitters.

Primary power sources are divided into three classes: batteries, commercial a-c and d-c power lines, and electromechanical systems.

Ordinarily dry cells were not considered as primary power sources until the advent of the low-drain transistor circuits. Storage batteries contained in vehicles, because of their heavy-duty capability and the recharging facility, were considered primary power sources. Low d-c voltages may be converted to high d-c voltages by dynamotors or vibrator power supplies, while the electron-tube filaments or heaters, relays and motors are operated directly from the storage battery.

Commercial power systems may be either a-c or d-c in nature and can range from the standard 115-volt, single-phase, source to 2,300-volt three-phase power utilized for industrial purposes. Primary a-c sources are available between 32 and 440 volts. In the United States, commercial a-c voltage is available at frequencies of 25, 40, 50 and 60 Hz. The 60-Hz source is the most widely used. In Europe, 220-volt a-c of 50 Hz is quite common.

Equipment designed to function with a-c current will be damaged by d-c current and d-c equipment will not operate on a-c current. Combination a-c—d-c equipment will operate well on either, providing that proper d-c polarity is observed.

Electromechanical systems, which employ rotating armatures, are widely used because they are portable and can deliver power where it is needed. Included in this category are gasoline-engine-driven generators, motor generators, rotary converters, inverters and dynamotors. The last three devices are driven by electricity. Vibrator power supplies are included with inverter systems, as a static means of producing a-c from a d-c source.

The basic a-c power supply is composed of a power transformer, a rectifier, filter capacitors, filter chokes and a bleeder resistor or voltage-divider circuit. Where it is desired to regulate the voltage constant in the circuit, a voltage regulating device must be added.

The power transformer serves to transform a-c power to some other voltage or to a series of voltages, depending upon the secondary windings. The rectifier serves to change the a-c provided by the transformer to a unidirectional or pulsating d-c. Rectifiers do this by passing current freely in one direction while obstructing the flow of current in the other direction.

The filter capacitors found in power supplies may be electrolytic, ceramic, mica or paper in construction and serve to filter, or "smooth-out," the pulsating d-c voltage passed by the rectifier. Filter chokes, or iron-core inductances, further smooth the pulsating d-c output of the rectifier, in conjunction with the filter capacitors discussed above.

Because of high-voltage surges and the fact that the filter capacitors remain charged when the power supply is turned off, a bleeder resistor is used across the output of the power supply. When tapped at appropriate locations, the bleeder resistor may also serve as a voltage divider. Its wattage must be sufficient to carry both the bleeder current and the current drawn by devices attached to the voltage-divider network.

Figure 4-1 below shows a representative high-voltage power supply, with bleeder resistor combined with voltage-dividing network.

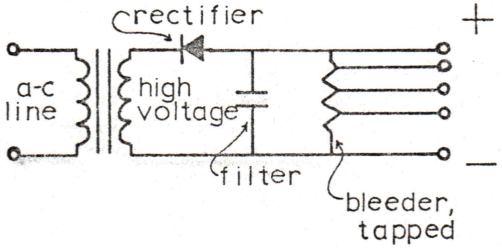


Figure 4-1. High-voltage power supply.

Rectifiers may be of the half-wave, the full-wave or the bridge-rectifier type. Half-wave rectifiers are used in many low-voltage power supplies and some a-c—d-c radio equipment. They are the least expensive and least bulky of the rectifiers. Full-wave rectifiers are used generally in communications equipment power supplies. They provide a wide range of output voltages with moderate currents and are highly efficient. Bridge rectifiers are used when it is necessary to obtain the maximum voltage across the secondary of the transformer. These circuits are used in precision electrical measuring equipment and in low-voltage plate supplies. They do not often use tubes, but rather copper-

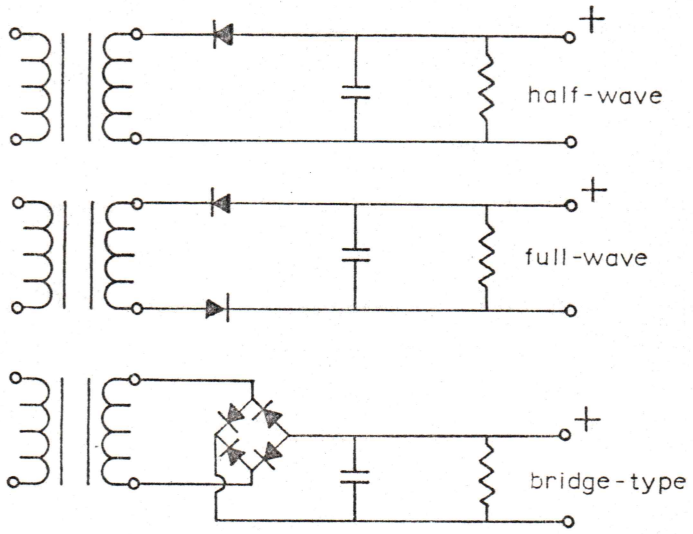


Figure 4-2. Rectifier types.

oxide, selenium or silicon rectifiers. Shown in Figure 4-2 are representative examples of the half-wave, full-wave and bridge-rectifier circuits.

Through the use of half-wave rectifiers it is possible to design voltage doubler and voltage multiplier circuits that step up the rectifier's output voltage without the use of bulky power transformers. It may be noted, however, that the constant voltage regulation of such circuits is extremely poor.

Figure 4-3 shows a low-voltage transistorized power supply.

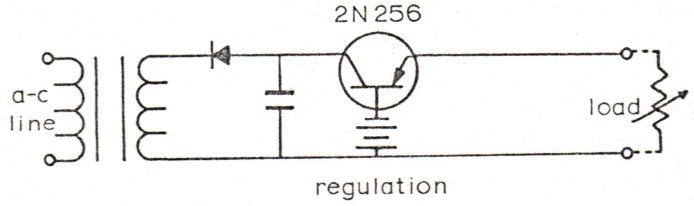


Figure 4-3. Transistorized low-voltage power supply.

POWER SUPPLIES

Varying voltages are required to operate the vacuum tube filament, plate and screen circuits or semiconductor devices of radio receivers and transmitters. These voltages are furnished by the power supply which provides an exact, regulated source of a-c filament power and smoothed, filtered a-c for the plates.

The A power supply, or filament power, is usually low-voltage-high-current and is provided by dry batteries in portable radios or by step-down transformers in fixed installations. Mobile and some portable units employ storage batteries, while genemotors or dynamotors are used in other circuits. The B power supply, or plate power, is most often high-voltage-low-current and is furnished by dry batteries in portable units. Rectifier-filter plate supplies, powered from standard a-c lighting circuits, are used to provide B supply in most stationary equipment. Dynamotors, powered by automobile or aircraft storage batteries, or gasoline-engine generators, furnish the plate supply for many semiportable radio systems.

Power supplies are classed in one of three types of systems: battery-powered, a-c powered and electromechanical powered units. Battery power supply is usually restricted to small, hand or back-carried portable transmitters and receivers and to combination units called transceivers. Low current drain is demanded of circuits to enable use of this type of power. Generally, radio units employing batteries for transmission and reception can be operated for several hours, intermittently, before batteries are exhausted. Certain sets use battery packs which supply current for the filaments, plates and grids, while other sets employ a separate battery for each function. Although dry batteries provide a smooth source of d-c, which enables simplified design and effective operation, they are extremely expensive to use and store for extended periods. Many hand-transportable units use rechargeable storage batteries in conjunction with vibrator power packs to provide a reasonably clean source of high-voltage d-c. This offers the advantage of more economical operation but combines with it the weight of the storage batteries and the

added trouble of maintaining and transporting the recharging equipment.

In units designed for operation from commercial a-c power sources, the power supply is composed of a power transformer, a rectifier, a filter section and a voltage divider. The majority of these units designed for use within the United States have been engineered to use 105 to 115-volt, 60 Hz a-c. In the transformer rectifier-filter system of a-c power supply, the transformer furnishes a method of providing increased or decreased voltage through normal transformer action. The transformer is generally tapped to give a low-voltage a-c for the filaments and a high-voltage source for the plate supply. In this circuit, the rectifier converts the a-c to a pulsating d-c and the filter section smooths the pulsating d-c to a steady, nonfluctuating d-c flow. This is accomplished with either a choke-input, or a capacitor-input, filter network. The voltage-divider, or bleeder-system, enables various d-c voltages to be provided for the operating requirements of the screen, plate and control- grid sections. Figures 4-4 through 4-6 illustrate, schematically, the various typical components of an a-c power supply.

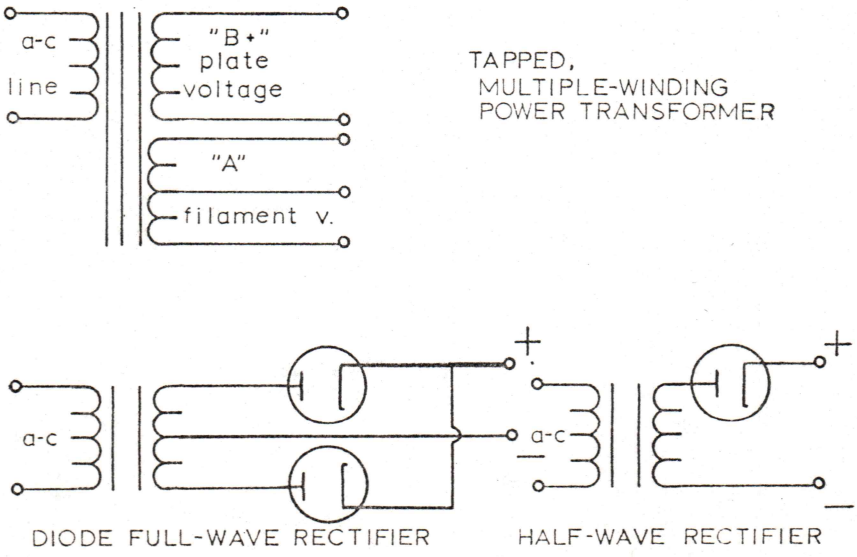
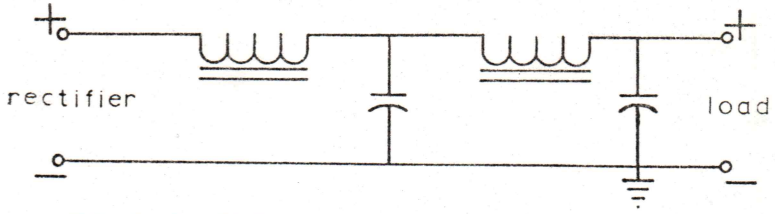
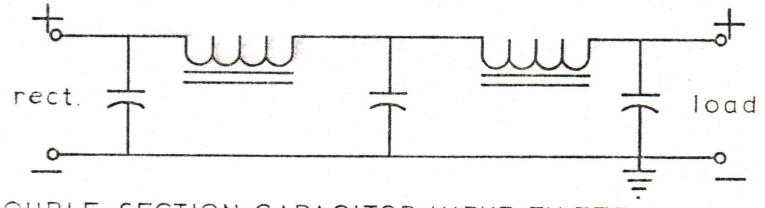


Figure 4-4. A-C power supply components.

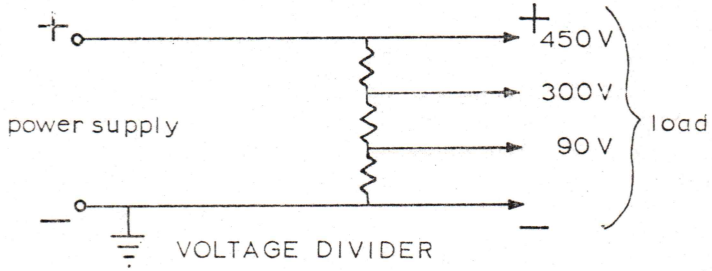


DOUBLE-SECTION CHOKE INPUT FILTER

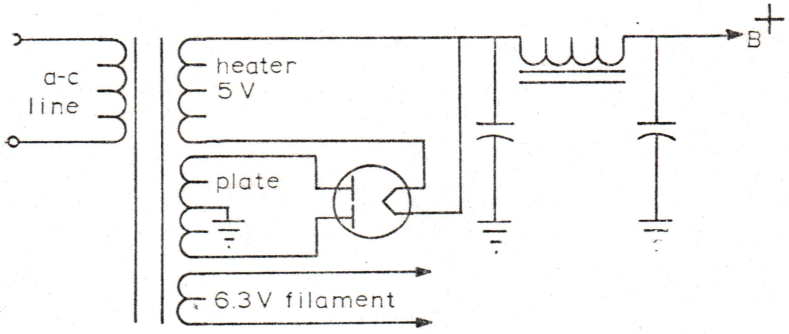


DOUBLE-SECTION CAPACITOR INPUT FILTER

Figure 4-5. A-C power supply filter networks.



VOLTAGE DIVIDER



TUBE POWER SUPPLY

Figure 4-6. Voltage-divider and A-C power supply.

Included in the electromechanical power units are dynamotors, motor generators, vibrator supplies and gasoline-engine generators. Dynamotors are a single-unit with a double armature wound on a single shaft, utilizing separate commutators. One winding serves as low-voltage electric motor which energizes, on the same shaft, a high-voltage d-c generator. They generally deliver from 300 to 1,000 volts and are powered by storage batteries of 6, 12, 28 or 32 volts. Motor generators are also known as genemotors and are essentially a dynamotor engineered for automobile and similar service. They are economical to operate and are well regulated. Their efficiency ranges between 50 and 60 percent, and deliver between 135 and 600 volts at various current ratings. Figure 4-7 shows a typical dynamotor circuit.

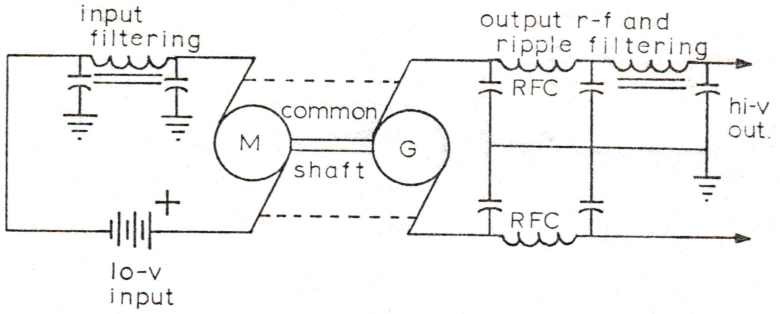


Figure 4-7. Dynamotor filtered power supply.

Vibrator supplies are electromechanical power supplies characterized by their efficiency of operation. They consist of a reed vibrator, low-voltage power supply, a rectifier and suitable filtering. There are two types of vibrator supplies: nonsynchronous and synchronous. The chief difference between them is that while the nonsynchronous vibrator supply requires a rectifier, the synchronous circuit (due to an additional reed) does not. In Figure 4-8 are shown both types of vibrator power supplies.

Gasoline-engine generators, supplying 115 volt 60-Hz a-c, are an effective source of field power and may be obtained to supply anywhere between 250 watts and several kilowatts. They consist of a two- or four-cycle gasoline engine directly connected

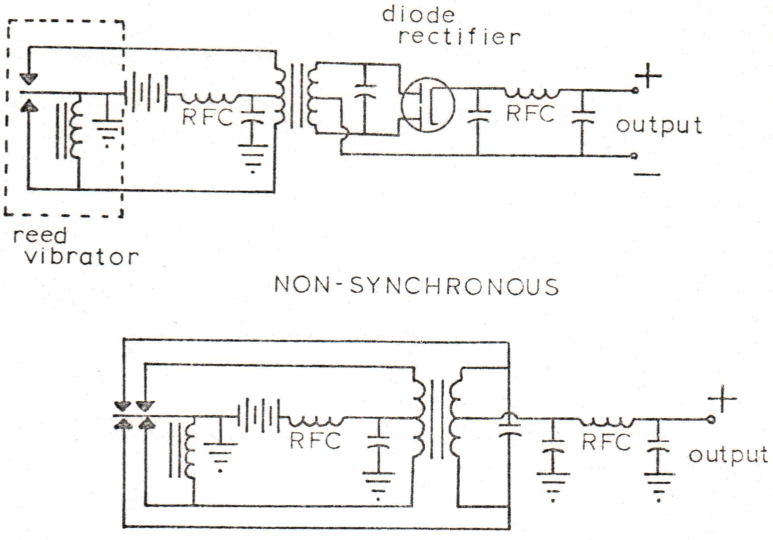


Figure 4-8. Vibrator power supply types.

by the drive shaft to an a-c alternator along with suitable shielding and r-f filtering. Units are available with self-starters and mufflers and may be equipped to charge their own 6- or 12-volt starting storage batteries. Some types are liquid-cooled and employ automatic load compensation; d-c types are also available.

RECEIVERS

The Tuned-Radio-Frequency Receiver

This receiver, also known as the t-r-f receiver, is composed of several stages of r-f amplification, a detector stage and several stages of a-f amplification. A block diagram is shown in Figure 4-9 with the signal illustrated graphically as it passes from stage to stage. The use of tuned r-f stages increases both the sensitivity and the selectivity of a t-r-f receiver, and the more stages that are used, the better both qualities are emphasized. Tubes used in r-f stages are generally tetrodes and pentodes. (See Figure 4-10, below, for a basic circuit.)

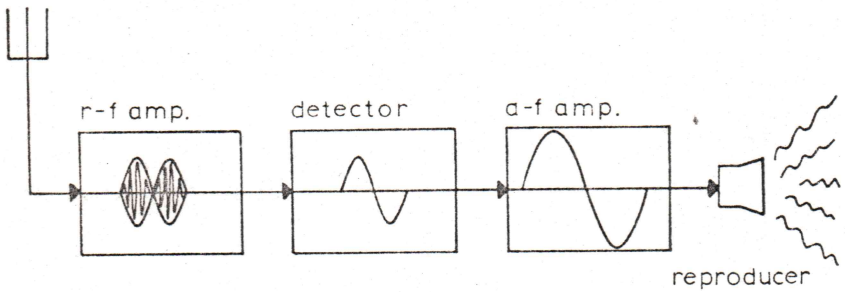


Figure 4-9. Block diagram for T-R-F receiver.

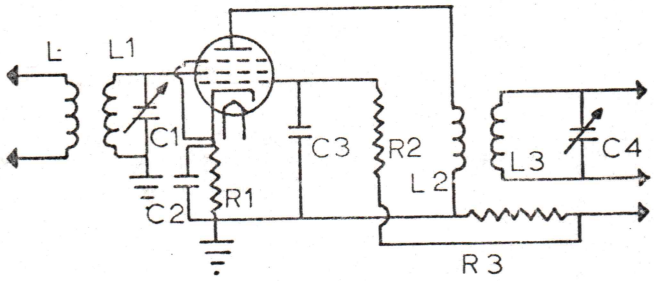


Figure 4-10. R-F stage.

The tuned circuit L_1C_1 is coupled to L which could be either the antenna coil or the primary (plate coil) of the preceding r-f stage. R_1 is the cathode bias resistor, while C_2 is the cathode bypass capacitor. The screen bypass capacitor is C_3 and R_2 serves as the screen voltage-dropping resistance. The second tuned circuit is formed by L_3C_4 which is coupled to L_2. The r-f transformer, it can be seen, is an air-core transformer and is composed of L_2L_3. Another r-f transformer is found at L L_1. These tuned circuits are adjusted by varying the capacitance and/or by adjusting brass or powdered iron cores (in the case of metal-core types). For wider frequency-range coverage, series of coils may be switched or plugged into the circuit in a bandswitching arrangement.

Because the voltage amplification is high in modern t-r-f sets, the input signal voltage is also high; the old, easily overloaded grid-leak circuit is almost never used. Diode detectors and power

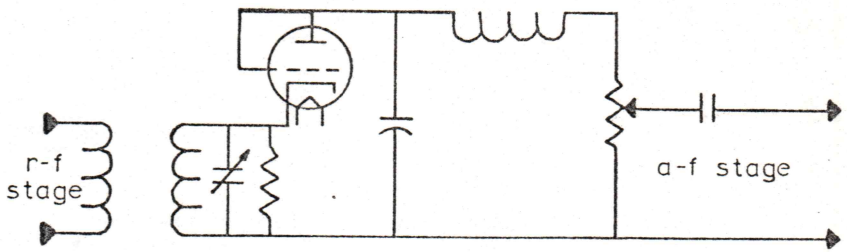


Figure 4-11. Detector stage.

detectors are most often employed. The schematic diagram of a typical detector stage is shown in Figure 4-11.

The volume control on receivers must be variable since the signals received by the antenna vary in strength. This gain (volume) control may be provided by varying either the grid-bias control or the detector diode output. (See these schematic diagrams in Figure 4-12 and Figure 4-13.) Another widely used method is automatic volume control (AVC), also known as automatic gain control (AGC), shown in Figure 4-14. This method is widely used in mobile receivers, where the variations in received signal strength demand such control. As the grid-bias voltage is increased, the signal is more suppressed and tends to stabilize the output of the receiver.

To further amplify the output of the weak-output r-f detector,

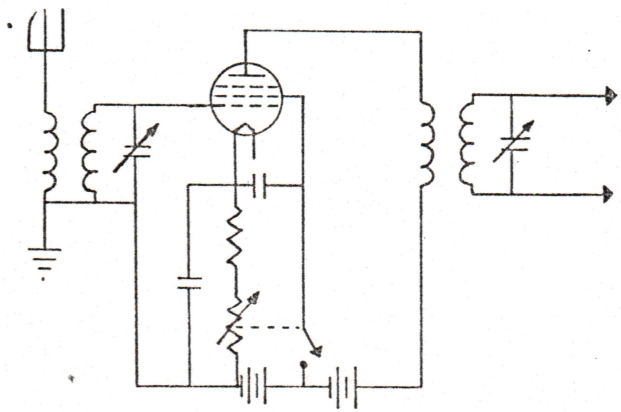


Figure 4-12. Grid-bias gain control circuit.

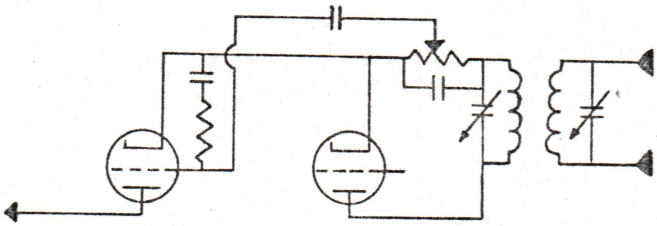


Figure 4-13. Detector-output gain control circuit.

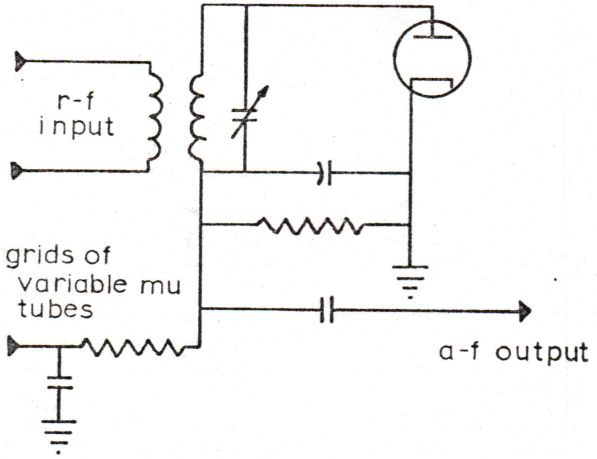


Figure 4-14. Automatic gain control (AGC) circuit.

some audio-frequency amplification is required. This may be in the form of a single tube for headphone operation or several stages to enable loudspeaker service.

It may be noted that most of the circuits in t-r-f sets must be shielded from each other in order to prevent inductive coupling between stages. Copper or aluminum is employed for r-f circuits, while iron is used for a-f circuits. This shielding is connected to the receiver chassis or common ground: Adjustments for tuning should be made with the shields in positions. Figure 4-15 illustrates a typical t-r-f receiver utilizing an r-f amplifier stage, a diode-detector stage and a final pentode a-f amplifier. The set is battery-operated.

The t-r-f receiver affords good results for the low- or medium-

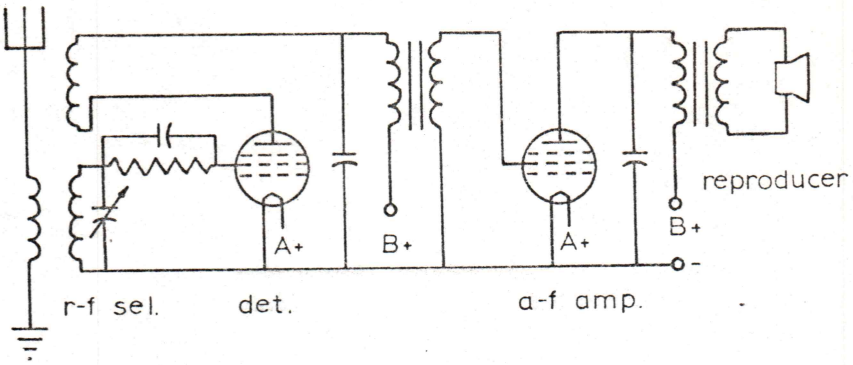


Figure 4-15. T-R-F receiver, two-tube.

frequency bands but its selectivity decreases when used in the high-frequency bands. In addition, its amplification efficiency decreases with higher frequencies. For greater efficiency with high-frequency signals, the superheterodyne receiver is employed.

The Superheterodyne Receiver

In the t-r-f receiver, the r-f signal was amplified directly at the signal's own frequency. The superheterodyne receiver makes use of an intermediate frequency (i-f) for the amplification of the r-f signal. This permits retention of all the modulation characteristics present in the other signal and results in much greater selectivity and amplification. Figure 4-16 shows a block

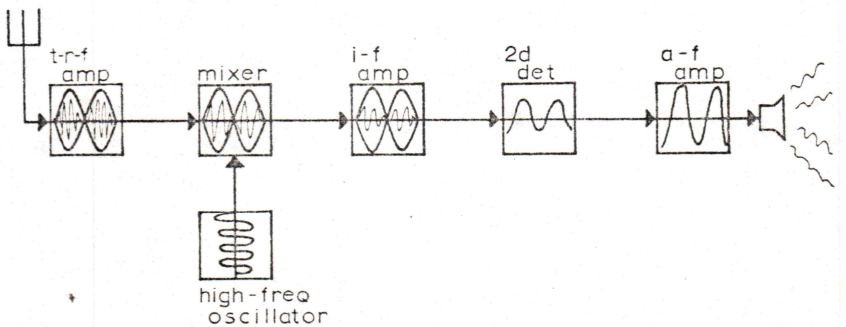


Figure 4-16. Block diagram for superheterodyne receiver.

diagram of the component parts of a typical superhet receiver and the modifications of the signals it receives.

The r-f signal is received in the antenna and enters the r-f amplifier. It then passes through the mixer stage, where it is mixed with another, unmodulated lower-frequency, r-f signal produced in the h-f oscillator. This "new" frequency, the intermediate-frequency (i-f), is then sent through several i-f amplifier stages and into the second detector stage. In the second detector section the signal is detected or demodulated. The demodulated signal is then fed through one or more stages of an a-f amplification and into the reproducer.

The oscillator and mixer stages of a superhet receiver are called the frequency converter, and their operation takes various forms. The oscillator output signal may be sent to the cathode, the grid or the suppressor-grid circuit of the mixer tube, or the mixing and oscillation may take place within a special pentagrid converter tube. The pentagrid converter is widely used in superhet circuits. The intermediate-frequency operates at the beat-frequency (difference between the r-f signal and the oscillator frequency) which in most broadcast A-M superhets is either 455 kHz or 465 kHz. In F-M broadcast band superhets the i-f is usually 10.7 MHz.

Through the adjustment of mica and air-trimmer capacitors or by tuning powdered iron cores, the i-f stages are sharply tuned for maximum amplification and selectivity. These stages control the well-known voltage amplification and selectivity capabilities of the superheterodyne receiver. Pentode tubes are most often used in i-f stages, as shown in Figure 4-17. R-f amplifiers are included to provide for unwanted signal image rejection and, in addition, improve selectivity. To provide for the reception of continuous wave (c-w) code signals, a circuit called a beat-frequency-oscillator (BFO) is used. It is done by a separate oscillator which is tuned to a frequency slightly different from that of the i-f so that it produces an audible tone. This frequency difference is often one of only 1 kHz, and thus a beat-frequency note is produced by the process of heterodyning. (See Figure 4-18 for adaptation of a BFO circuit.)

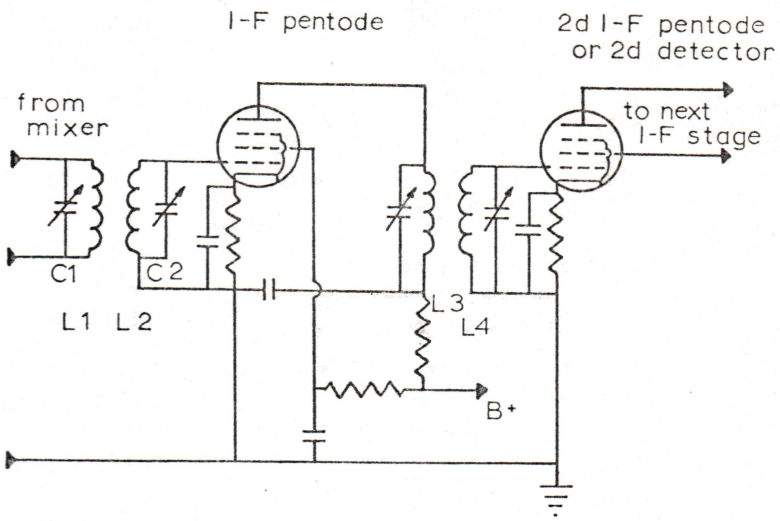


Figure 4-17. Pentode I-F amplifier.

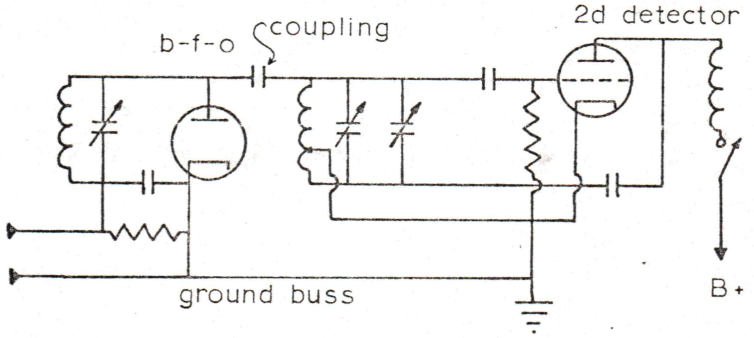


Figure 4-18. Beat frequency oscillator (BFO).

Detection stages used in superhets consist of essentially the same types as those found in t-r-f receivers and usually have AVC action applied to some of the stages before the second detector (with the exception of the oscillator). Finally, the a-f stages of superheterodyne receivers are about the same as those found in t-r-f sets, their complexity being dictated by local audio needs.

Figure 4-19 shows a simple, battery-operated superheterodyne receiver employing some of the stages that have been discussed.

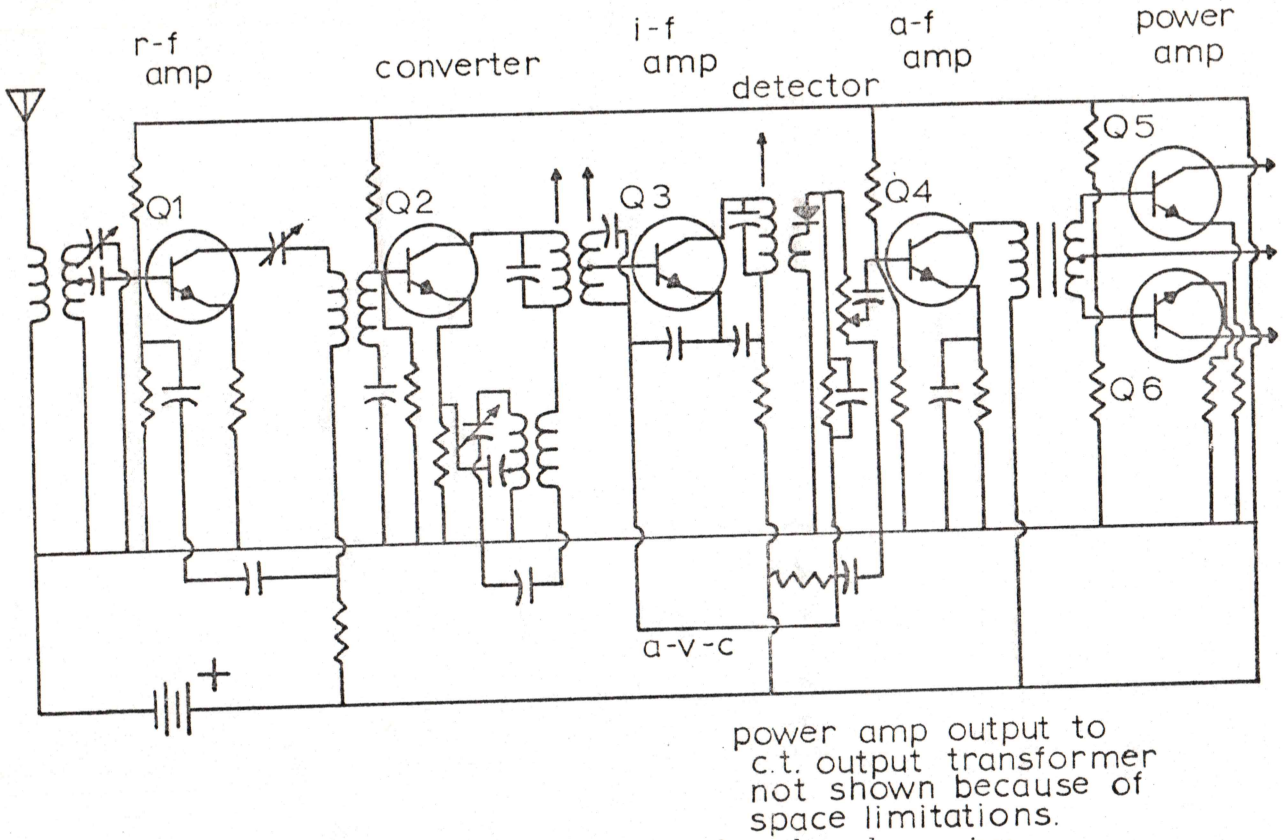


Figure 4-19. Typical battery-operated superheterodyne receiver.

For the most part, all modern radio receivers with which the electronic investigations technician is called upon to deal will be of the superheterodyne type.

TRANSMITTERS

Oscillators

Vacuum tubes have the capability of generating a-c power through their ability to amplify signals sent through them. This a-c power generation is termed "oscillation," and it is used widely in radio circuitry. Oscillators are essential to transmitters and superheterodyne receivers, in addition to such testing instruments as signal generators and grid-dip meters. Output voltage feedback is the key to the operation of an oscillator. In this circuit the plate circuit is coupled to the grid circuit so that some of the tube's output is fed back to the grid. When amplification is advanced sufficiently the tuned circuit begins to oscillate. This feedback may be provided through coupling by means of capacitance, inductance or resistance. Through varying the L-C ratio, oscillations over the complete radio spectrum are produced, with the vacuum tube serving as an electrical "valve" to regulate the electron flow and thus sustain the oscillations in the circuit. Electron flow in a parallel-tuned circuit is shown by the generation of a-c oscillations in Figure 4-20.

The function of the amplifier is the amplification of the signals of the plate circuit. The amplifier's frequency has to be that of the oscillator's tank circuit resonant frequency. Voltage is then

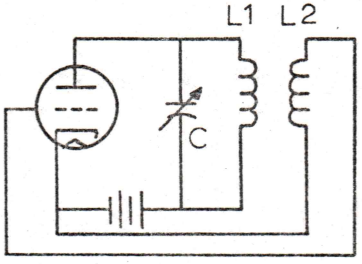


Figure 4-20. Basic oscillator circuit.

induced in coil L_1 and consequently sent to the grid of the tube causing oscillations to occur. Considerable negative grid bias is necessary in oscillator circuits, thus resulting in the flowing of plate current only when the a-c grid voltage approaches its positive apex. In addition, the grid draws current supplied by the oscillations in the L-C tank section.

Oscillators usually are either self-excited or of the crystal-controlled type. Typical of self-excited oscillators are the Hartley, the Colpitts and the tuned-plate tuned-grid oscillators, shown in Figures 4-21 through 4-23. If an exact, inflexible value is desired

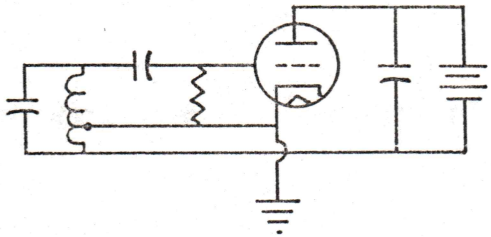


Figure 4-21. Hartley oscillator.

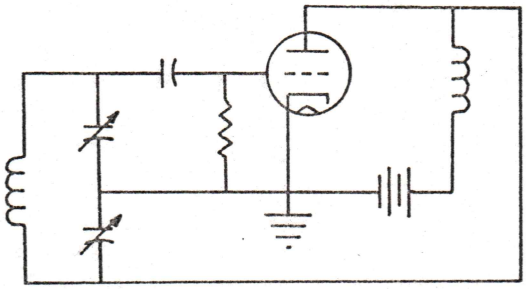


Figure 4-22. Colpitts oscillator.

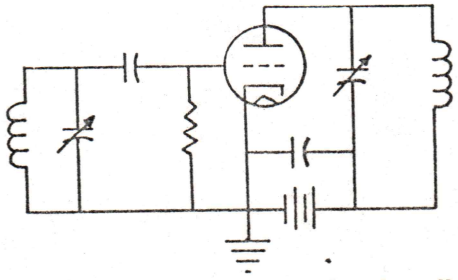


Figure 4-23. Tuned-plate, tuned-grid oscillator.

in the frequency of an oscillator, crystal control is utilized. Through the piezoelectric effect, a quartz crystal slab will vibrate when alternating voltage is fed through it at its resonant frequency. This crystal circuit, as can be seen in an examination of Figure 4-24, is equivalent to a tuned circuit of high-Q, although

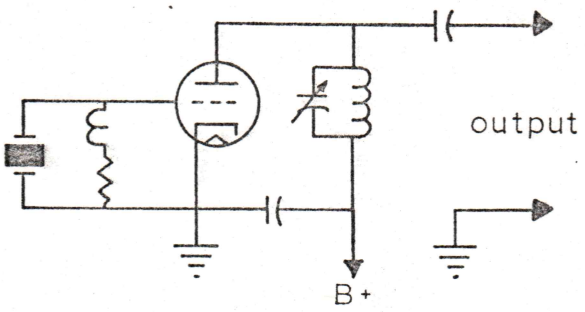


Figure 4-24. Triode crystal oscillator.

of fixed frequency. The circuit shown is the equivalent of the tuned-grid, tuned-plate, self-excited circuit. Another common type oscillator is the Pierce crystal oscillator circuit shown in Figure 4-25. It requires no tuning control and the crystal is connected directly between the grid and the plate. Since the crystal substitutes for the tuned circuit, it may be seen that the circuit accomplishes the same end as that of the Colpitts oscillator.

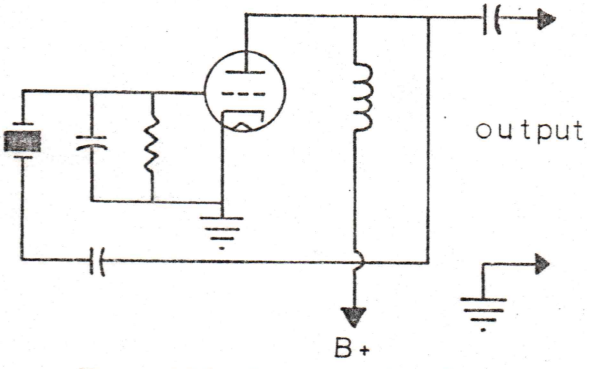


Figure 4-25. Pierce crystal oscillator.

The purpose of the crystal oscillator is only to generate the desired frequency; any amplification must be provided through r-f power amplifiers. Radio-frequency power amplification is usually provided by class B or C amplifiers, since power energy is required to replace that lost in dissipation at the antenna. When an oscillator is coupled to an amplifier it is termed a "master-oscillator power-amplifier" (MOPA) and permits r-f energy to flow only to the grid of the r-f amplifier, while preventing the flow of oscillator tank circuit d-c to the same grid. The MOPA also has a tuned input and tuned output circuit, so that it resembles the tuned-grid, tuned-plate oscillator. A buffer amplifier stage may also be utilized to isolate the oscillator from the r-f amplifier. A block diagram of such circuitry is shown in Figure 4-26.

Due to the nature of the crystals, there is a frequency limit for which the crystal can be ground. Circuits can be employed, however, to multiply the crystal oscillating frequency to that desired. These circuits are termed "frequency multipliers." They employ harmonic multiples of the oscillator frequency, in addition to tuned circuits, to raise the operating frequency to that which it is desired to radiate. These circuits are inserted before the r-f power amplifier, and needless to say, power efficiency suffers to some extent when they are used.

Modulating Transmitters

Varying the amplitude or the frequency of a continuous-wave radiation, such as that radiated by the transmitters previously discussed, results in the ability to transmit voice frequencies impressed on the wave. This is termed "modulation." Two types are employed—amplitude-modulation (A-M) and frequency-

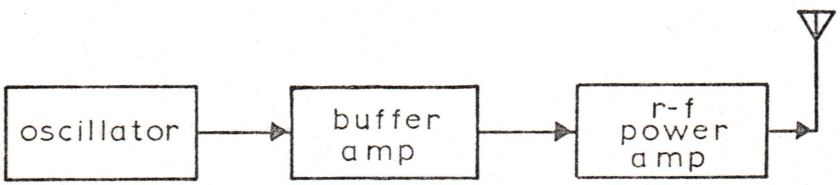


Figure 4-26. Master oscillator–power amplifier (MOPA) transmitter.

modulation (F-M). Amplitude modulation is the regulation of transmitter r-f output at an audio-frequency magnitude.

When a-f is high, the amplitude of the wave must cycle very quickly, while the reverse is true in the case of the lower a-f waves. It is evident that r-f energy is increased when the a-f signal becomes more intense. In this way are the a-f changes reflected exactly in the r-f output. By varying the voltage on an electrode in the final r-f power amplifier the transmitter becomes amplitude-modulated. Varying the plate voltage of the final r-f amplifier tube at audio frequencies causes A-M signals to be transmitted.

To produce this effect by varying the plate voltage of the final r-f stage, it is necessary to generate an audio voltage. Microphones could accomplish this but their output is usually only a fraction of a volt. What is done is to employ two amplifiers. The first one is called a speech amplifier and is usually a class A amplifier. Its output is then fed to the grid of an audio power amplifier called a modulator. This amplifier may be of the class A, class AB or class B type, as long as it provides necessary undistorted power. The modulator may be either single-tube or push-pull output. The power output of the modulator stage is then fed to the plate of the final r-f amplifier.

In this way is the a-f signal amplified and fed to the r-f carrier wave causing plate voltage of the r-f amplifier to vary at an audio rate and resulting in amplitude modulation. Figure 4-27 shows the process in block form, along with the wave frequency changes.

A typical integrated A-M transmitter diagram is shown in Figure 4-28. It is a Hartley oscillator circuit in conjunction with a single-tube speech amplifier and a master-oscillator power-amplifier.

Frequency-modulation (F-M) transmitters employ a different principle of wave transmission which results in the elimination of natural electrical noise and man-made interference, such as static from automobile ignitions, diathermy machines, fluorescent signs, atmospherics, lightning and other radio transmitting stations. The fundamental difference between F-M transmissions and A-M

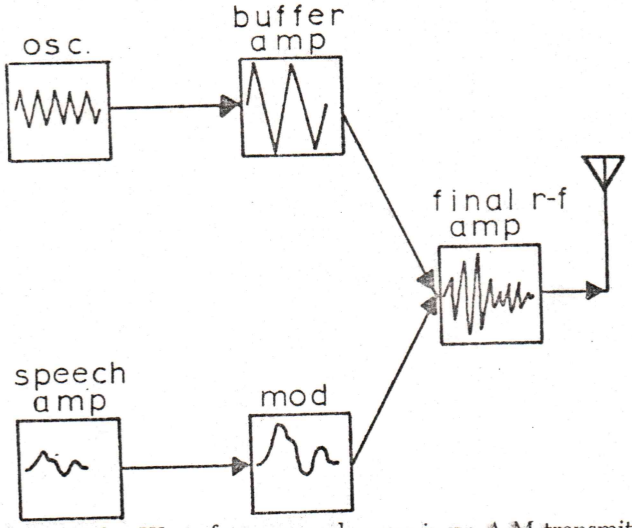


Figure 4-27. Wave frequency changes in an A-M transmitter.

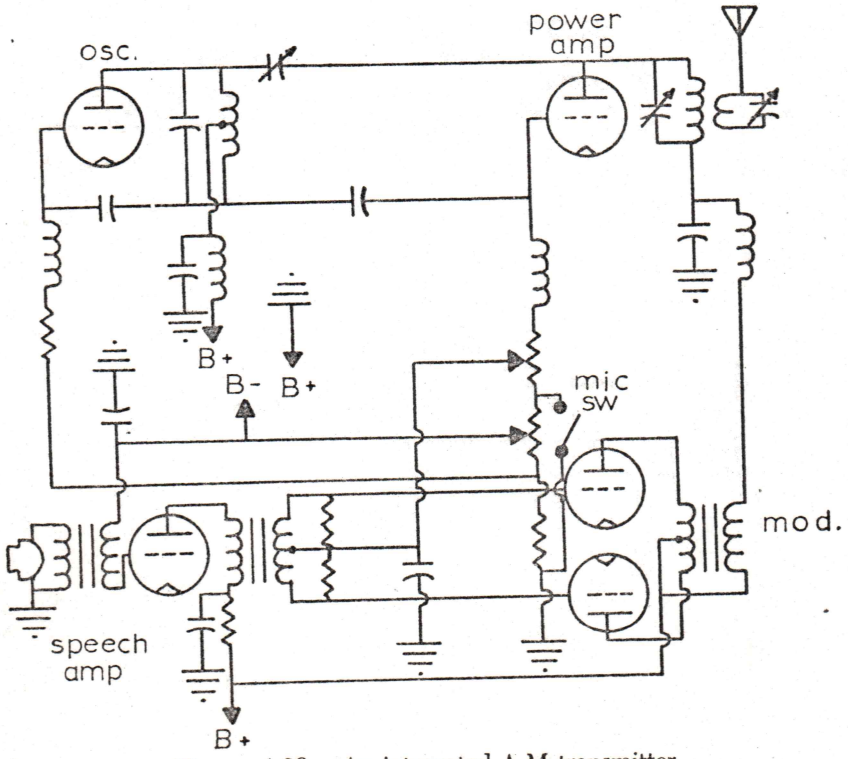


Figure 4-28. An integrated A-M transmitter.

transmissions is that in F-M signals the frequency of the waves is varied rather than the magnitude of the waves as in A-M signals.

When the frequency of the carrier wave is varied according to the number of Hertz directly as the a-f input, F-M waves result, as shown graphically in Figure 4-29, composed with waves of A-M type and of the typical unmodulated r-f carrier. As can be observed, the amplitude of the F-M wave remains constant, while the changes in frequency take place as modulated by the speech amplifier.

Receivers designed for F-M reception are responsive only to signals of varying frequency and largely reject those signals which vary in amplitude. Among the basic types of F-M transmitter circuits is the simple condenser microphone frequency modulator. In this circuit, which is exhibited in Figure 4-30, the microphone shunts a tuned oscillator and causes the capacitance of the circuit to vary by movement of one of the two plates of the condenser

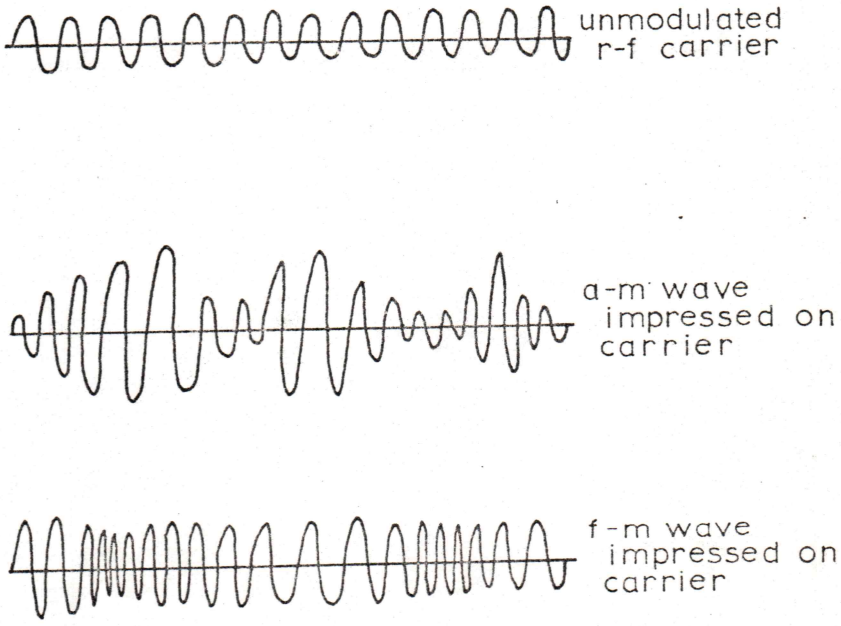
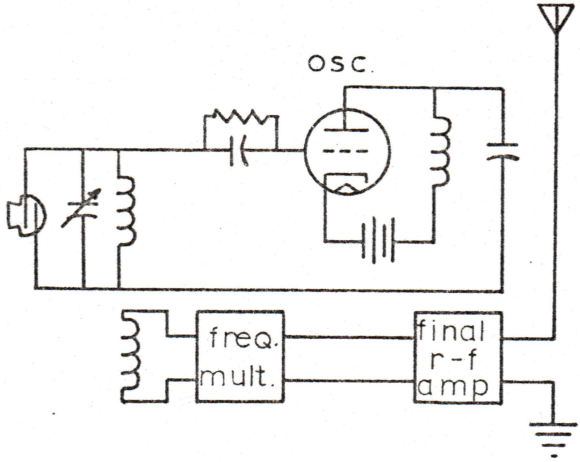


Figure 4-29. A-M/F-M wave differences.



SHUNT-FED
HARTLEY OSCILLATOR

Figure 4-30. F-M transmitter employing condenser microphone.

microphone when the diaphragm is set in motion by voice frequencies. This type of F-M circuit is known as mechanical modulation.

Other types include reactance-tube modulation and Armstrong phase-modulation circuits. In reactance-tube modulation the r-f wave is modulated initially at its oscillator, while in the Armstrong system of phase-modulation the r-f wave is modulated in a following stage. Figures 4-31 and 4-32 illustrate, in block form, these two types of F-M transmitters.

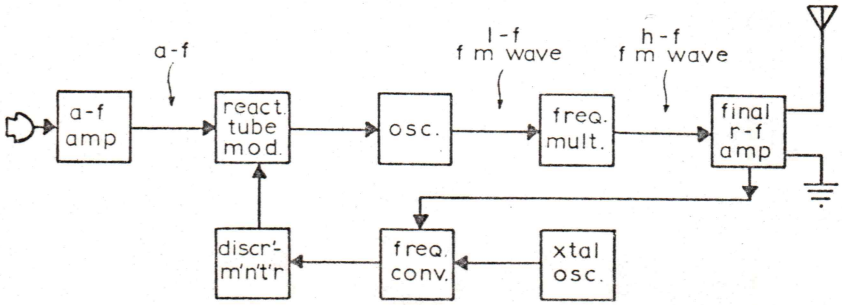


Figure 4-31. Reactance-tube modulation.

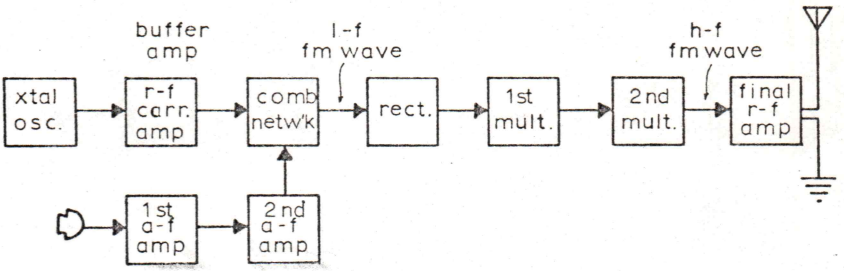


Figure 4-32. Armstrong phase modulation.

The reactance-tube F-M transmitter usually consists of a reactance-tube modulator, an electron-coupled oscillator-doubler, or push-pull doubler, and a push-pull r-f power amplifier applying an r-f signal to the antenna. The oscillator of the ordinary electron-coupled oscillator-doubler is of the Hartley type wherein the primary of the coil is the grid section and the secondary is the plate in the oscillator. Frequency doubling takes place in the plate circuit of the tube, which also provides for coupling to the buffer amplifier.

In this type of transmitter, the frequency modulation is created in the reactance-tube modulator, when the tube is shunted across the oscillator tank section, and the filament becomes capacitor-like in action. Varying the audio frequencies fed from the microphone through the speech amplifiers to the grid of the reactance-tube modulator furnishes a changing capacitive action on the tank of the oscillator circuit. This causes the frequency of the oscillator to vary at an audio rate. When this F-M signal is multiplied in the plate circuit of the oscillator and applied to the second multiplier and the resulting wave passed through the r-f power amplifier, the completed F-M signal is ready to be applied to the antenna.

The Armstrong phase-modulation system of F-M transmissions is similar to the reactance-tube modulator previously discussed and differs only in the plate circuit stage of the buffer amplifier. It includes a new component, the nonlinear reactance-modulator coil, which serves to modulate the transmitter. This phase-modulation system consists of the process of altering the fre-

quency of the r-f waves which have already been created at a constant frequency. Because of the fact that modulation in the phase-modulator occurs after the buffer amplifier stage, the oscillator may be crystal-controlled and frequency-stabilizing stages may be eliminated. This, perhaps, is the primary reason that phase-modulators are often preferred over reactance-tube modulators.

F-M receivers are necessarily more complicated than A-M receivers. Two stages are employed in the F-M receiver which are not used in the A-M receiver; these are the limiter and the discriminator or frequency detector. The reception of F-M signals demands that superheterodyne receivers be used exclusively in order to boost the weak signals to a point where they can be influenced by the limiter. A graphic block diagram of a typical F-M receiver is shown in Figure 4-33. Note the similarity to an A-M superhet.

F-M receivers must be capable of extremely wide-band reception, must possess a limiting stage to screen out all amplitude variations of the passed signals and must employ a discriminator (frequency detector) to convert the variations of frequency to amplitude changes. F-M intermediate-frequency stages are designed to allow a wider band of frequencies to pass through their broadly-tuned circuits.

The F-M limiter screens out amplitude-modulation from the received signal and allows only F-M signals of unvarying amplitude to reach the discriminator stage. It is here that the F-M

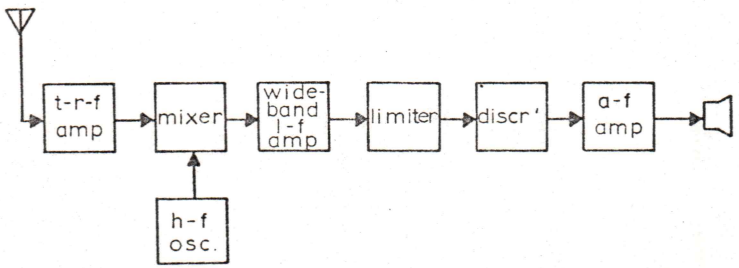


Figure 4-33. Block diagram of typical F-M receiver.

receiver rejects the natural and man-made noises of the A-M type which travel along with the transmission wave and are amplified by the i-f stages up to the limiter. The limiter removes these noises from the signal before it is fed to the discriminator stage. In this process the signal is further amplified and the negative and positive peaks of the waveform are clipped off, leaving an F-M signal of unvarying amplitude.

The discriminator stage of the F-M receiver changes the frequency variations of the frequency-modulated r-f waves to an audio signal and is roughly comparable to the detector in an A-M receiver, wherein the amplitude changes of the amplitude-modulated r-f waves are converted to an audible signal. Probably the most common type of discriminator is the Foster-Seeley circuit, which is characterized by the variation of the signal frequency back and forth across the resonant frequency of the discriminator, with the resulting production of an a-c voltage corresponding to the same frequency as the original voice modulation. This a-c voltage is passed on to the audio-amplifier through a capacitor.

Normally, the audio output of the discriminator circuit is fed through several stages of audio amplification and thence to a loudspeaker. There a-f amplification stages are of a type similar to those found in other varieties of receivers. Thus by the addition of two stages—the limiter and the discriminator—to the standard superheterodyne circuit, the elimination of natural noise and man-made static is accomplished. In addition, due to the wide band-pass of the F-M receiver, a greater range of audio-frequencies may be accepted, resulting in the capability of what is termed "high-fidelity reception."

It should be realized that v-h-f waves behave in a manner similar to light waves. V-h-f signals are often blocked by steel frame buildings, forests and mountains. They are primarily line-of-sight signals. In contrast to their distance limitations, v-h-f transmitters require less power per given unit of distance than do m-f transmitters and generally are of less weight than m-f transmitters.

ANTENNAS

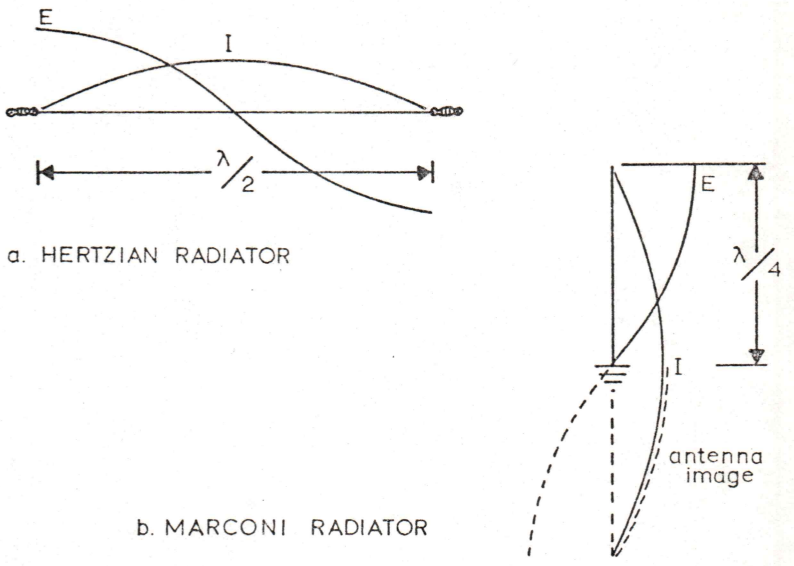
When the r-f signal is sent out of the final amplifier of the transmitter, it is necessary to provide a length of conductor which will radiate the r-f energy into the ether. These radiators are known as antennas and are used also by the receiver to pick up the transmitted intelligence.

The antenna, when used with a transmitter, radiates an electrical field (r-f energy) through space. The receiving antenna is cut through by this r-f field, causing voltages to be induced in it. These voltage variations are received, detected and amplified in the receiver and produced as sound. Antenna design is critical when used for r-f transmission and of less importance when used for reception of r-f signals. An antenna which would serve as a makeshift receiving antenna would result in great loss of efficiency when used for transmitting on a frequency differing from that for which it was specifically designed.

Antenna systems consist of a coupling device (antenna coupling coil), antenna transmission line and the antenna itself. The two basic types of antennas are the Hertz half-wave radiator and the Marconi quarter-wave radiator. The Hertz half-wave antenna is a self-tuned radiator generally cut to the frequency, which needs no ground or counterpoise. It is the most efficient type of antenna. The Marconi quarter-wave radiator is a quarter-wavelength long but differs in that it is neither grounded at one end, nor used with a counterpoise (a series of wires buried in the ground or suspended directly beneath the radiator). The half-wave antenna is of a length equal to one-half of the wavelength of the transmitted signal and must be cut or tuned to this distance in order to be in resonance (to radiate efficiently). The Marconi quarter-wave antenna is cut or tuned to one-quarter the wavelength of the transmitted signal, and the ground or counterpoise provides an exact image of this signal so that the half-wave signal is reproduced.

Antennas behave like a resonant circuit, since they have both capacity and inductance and resonate at the particular frequency to which they are tuned.

The grounded quarter-wave radiator behaves similarly to an



4-34. Basic characteristics of Hertzian and Marconi antennas.

ungrounded half-wave radiator. Figure 4-34 illustrates the basic characteristics of Hertzian and Marconian radiators. Antennas for the higher frequencies are of relatively shorter length, while low-frequency antennas are of relatively greater length. The lower the frequency, the longer the wavelength. This relationship is expressed in the following formula:

$$\text{Quarter-wave length (in feet)} = \frac{300}{\text{wavelength (in meters)}}$$

or

$$\text{Frequency (in MHz)} = \frac{300}{\text{frequency (in MHz)}}$$

Proper antenna length may be easily determined by the formula shown below:

$$\text{Wavelength (in meters)} = \frac{468}{\text{frequency (in MHz)}}$$

or

$$\text{Half-wave length (in feet)} = \frac{236}{\text{frequency (in MHz)}}$$

Signals emanating from transmitting antennas that are vertically polarized are received most efficiently by vertical receiver antennas, while signals from horizontally polarized transmitting radiators are received best by horizontal receiver antennas. It is well to remember also that most dipole antennas are not omnidirectional radiators and that transmitting range may be affected by positioning of the radiator. Figure 4-35 shows various types of radio antennas.

Antennas are often decreased or lengthened electrically, while maintaining a static physical length, by a process termed "loading." If the antenna is too short for the particular wavelength, an inductive reactance (a coil) is added, while if the antenna is too long a capacitive reactance is added. Loading an antenna produces a decrease in efficiency since the coil cannot radiate, and the resistance of the coil must be added to the resistance of the entire system.

Loop antennas are very directional radiators and receive much more efficiently in a direction in line with the loop axis. They have the capability of transmitting or receiving a signal strongly

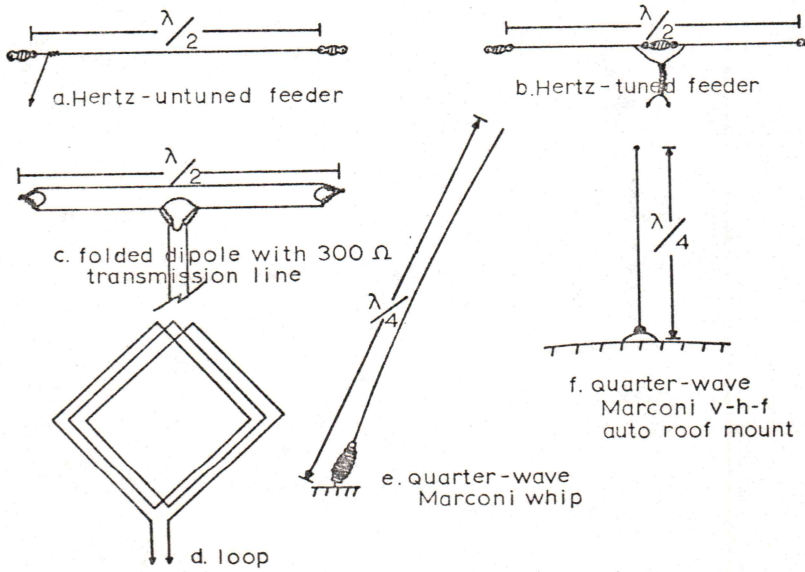


Figure 4-35. Basic antenna types.

in a desired direction and eliminating or receiving virtually no signal at all in a direction 90 degrees from the axis of the loop. Their principal use is in radio direction-finding or radio positioning.

Transmission line, the feed-in or feeder that carries the r-f energy from the transmitter to the antenna, occurs in three types: single-wire, two-wire and coaxial cable. Single-wire feeders usually have an impedance of about 500 ohms, while two-wire lines vary in impedance between 400 and 800 ohms. Coaxial cables may vary between 50 and 75 ohms. It is important to match the impedance of the antenna to that of the transmitter or receiver. This is often done by antenna line-matching transformers or a tap on the output-amplifier tank circuit. Transmission-line length is critical in resonant feeders and not critical in circuits employing untuned, nonresonant feeders.

Transmission lines are coupled to transmitters by one of three general types of coupling systems: direct-coupling, inductive-coupling or link-coupling. Direct-coupling is the simplest and is used with the single-wire-fed or end-fed Hertz radiator. As shown in Figure 4-36(*a*), the antenna is connected through a blocking capacitor directly to the plate tank circuit. The capacitor prevents high d-c voltage from appearing on the antenna and is thus safer to handle. Inductive-coupling employs a transformer effect inductively coupling a tuned circuit to the plate tank circuit, as shown in Figure 4-36(*b*). This type of coupling is widely employed and is often used in conjunction with variable inductance-capacitance networks to load the antenna for use on various frequencies. Link-coupling, seen in Figure 4-36(*c*), is a method of coupling higher-powered transmitters to remote antenna tuning units. The links consist merely of a few turns of wire around the antenna coupling coil and the plate tank coil, placed on the low r-f voltage side of the coil. Antenna tuning is accomplished most often by circuits shown in Figure 4-37.

Tuning a very short length antenna is shown in Figure 4-37(*a*), while Figure 4-37(b) exhibits a method used for very long antennas. Vehicular whip antennas for variable frequency oscillators may be tuned by the method shown in Figure 4-37(*c*).

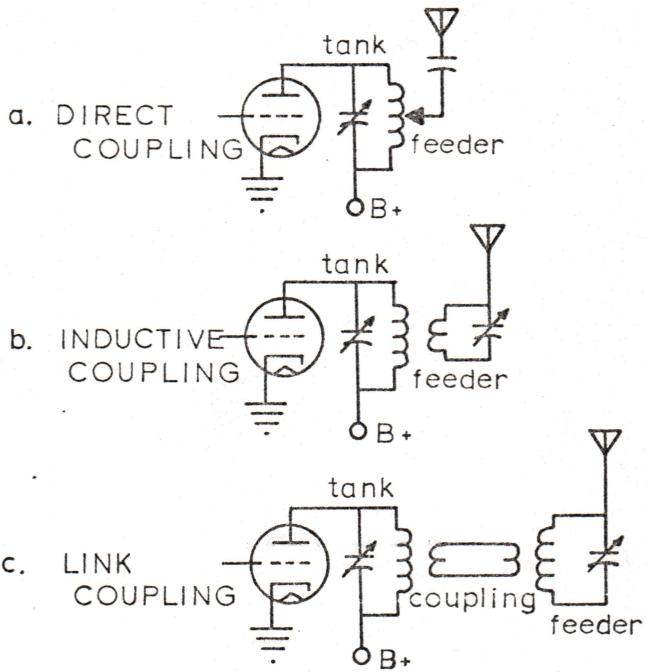


Figure 4-36. Antenna-coupling methods.

FIELD MAINTENANCE

The sound technician will often find himself called upon to service certain radio units in the field, in addition to maintaining his own radio surveillance equipment. This maintenance definitely should not begin in the field but must be anticipated and attended to long before the time that the unit requires field attention. The system of preventive maintenance is of prime importance to the continued effective functioning of radio equipment. This operational check-out system is carried on daily, with weekly inspections, supplemented by periodic tuning adjustments of transmitters required by law (see appropriate communications codes). It will result in greatly improved service and lengthened operational life of the equipment concerned.

Every day a few minutes of care should be devoted to ensuring that the equipment is free of dirt, dust, moisture or fungus and that all cables, plugs, and jacks are clean and properly

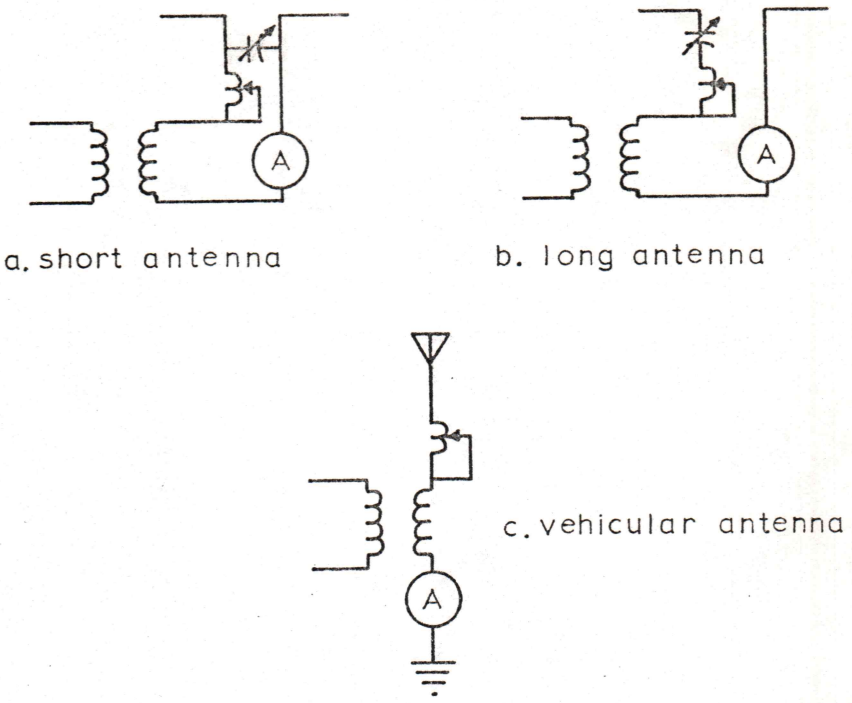


Figure 4-37. Typical antenna tuning methods.

adjusted. A check should be made to see that all components are present and that no part is receiving undue wear or abuse. Thorough equipment inspections should be made with the aid of an equipment and operating checklist about once a week and especially upon the return of the special equipment from field operations. This inspection should include an operating test, and any deficiencies noted should be repaired or adjusted as soon as is practicable.

Below will be found a suggested checklist with which to approach the establishment of a preventive maintenance program.

INSPECTION CHECKLIST

1. *Batteries*
   ( ) Cleanliness of battery, box, cables and terminals
   ( ) Rigidity of battery installation

( ) Insulation of cables—soldering and free from corrosion
( ) Test under load, replace if borderline

2. *Receivers*
   ( ) Overall cleanliness
   ( ) Mechanical connections, inside and outside
   ( ) Tightness and cleanliness of switches—replace broken knobs
   ( ) Tight-soldered joints
   ( ) Cleanliness of headset—check cord in particular for defects
   ( ) Tube or transistor seating
   ( ) Fuses
3. *Transmitters*
   ( ) Overall cleanliness
   ( ) Mechanical connections, inside and outside
   ( ) Cleanliness of meters—include operational check
   ( ) Tight-soldered joints
   ( ) Microphones—check cords and operation
   ( ) Tube or transistor seating
   ( ) Fuses
   ( ) Actual plate or collector current measurements compared with schematic values for normal operation
4. *Cables*
   ( ) Overall cleanliness and condition of cables and cords
   ( ) Opens and shorts
   ( ) Plugs and connectors
5. *Antenna Section*
   ( ) Condition of insulators and standoffs
   ( ) Overall condition of antenna
   ( ) Antenna free from ground
6. *Cases*
   ( ) Overall tightness and soundness
   ( ) Overall cleanliness and condition
7. *Accessories*
   ( ) Complete and in good condition

During field operation keep a careful record of the hours of use to which battery-operated units are subjected. This pro-

cedure will pay off in many cases by the prevention of functional failures. For important missions the use of fresh, new batteries is recommended, especially in the subminiature devices used in surveillance radio and surreptitious sound recording instruments. In the event of decreased operating efficiency of transmitters and receivers, attempt to change the location of the antenna. Often a change of a few feet will make a great difference in operating characteristics.

When using squelch equipped receivers and trouble is encountered receiving a transmitted signal, try turning off the squelch circuit. Some increase in sensitivity may be noticed, and if carrier is detected, attempts at communication are probably being made. Some advantage may be gained in utilizing coaxial antenna extension cables to position the antenna at a more effective location in stationary posts when portable units are in service. This same method may offer some benefit when using portable units in undercover automobiles and a window-clip antenna can be tolerated. If the window-clip antenna would disclose the intentions of the investigators, a coaxial antenna extension cable may be fitted or clipped to the car's existing broadcast antenna. The auto antenna should then be operated fully-extended for optimum results. Probably the most effective technique is the mounting of a fixed-frequency antenna, employing base-loading or a shorted-stub. This would be quite useful in a vehicle used primarily for monitoring of clandestine transmitters.

Chapter 5

OPERATIONAL TECHNIQUES

THIS CHAPTER WILL encompass some of the routine and special considerations encountered in the application of electronic audio surveillance techniques to field operations. Included herein will be subdivisions dealing with the disguise of all types of audio equipment installations to include microphones, wiretaps and surveillance radio transmitters and a section covering the disguise and selection of vehicles, tools and equipment. Antenna considerations and siting for transmitters and receivers and the use of field expedients will be detailed in the following section. The next two portions will deal with operational aspects of communications monitoring and the employment of voice and signal actuators. Following this will be a part detailing the use of automobile tailing transmitters and elements of radio-direction-finding used in conjunction therewith. A final section details the investigative applications of audio systems, telephone systems and radio systems.

DISGUISE OF INSTALLATIONS

Microphones

The placement of microphones within a room offers a challenge to the technician to develop an innovation that has not been previously discovered by countermeasures personnel. Microphones actually placed within a room are limited in their placement by their size, the interior configuration, acoustics and trim of the room, the length of the cable run and the time period in which the technician has access to the room. Microphones have been hidden in draperies, wainscoting, door frames, moulding,

floors, ceilings and in window casements. They have been concealed in bookcases, flower planters, light fixtures, line power receptacles, furniture that was unlikely to be moved, under carpeting, in shallow depressions under wall paper, in table and floor lamps, inside telephone instruments and ringer boxes, in heater ducts, air vents and registers, inside TV, stereo and radio sets, inside intercom sets, and in doorbell or chime housings. They have also been laid out in the open on floors or on tops of shelves. The author remembers one case in 1958 where the investigator lay behind a sofa with his recorder and extended his arm, holding the microphone, under the sofa in order to record the conversation of two persons seated thereon!

Assume, then, that the microphone may be hidden virtually anywhere. The next problem is to conceal signs that any "carpentry" work has been done. This includes the meticulous cleaning of the area in which the installation was made. For this purpose a small, inexpensive vacuum cleaner is appropriate to remove wood shavings, wire clippings and plaster dust. The area of installation of the microphone must be refinished so that it resembles, as closely as possible, the original finish on the surface in which it is installed. A selection of quick drying lacquers, a bar of soap along with some oil tints and some pastel water-based paint have been found to have considerable utility value. A set of pastel chalks has been found useful to tone down a short run of double-cotton covered wire.

Wiring may be either hidden or run out in the open disguised as some other type of wiring. In the concealment of wiring it may be run by shortest practicable route to the nearest moulding, which may be removed and the microphone wiring hidden behind it before it is replaced. The nail holes in the moulding may be re-puttied with stained putty, or filled with soap tinted with oil colors. Number 32 magnet wire may be run, for short distances, across a pastel-painted plaster wall and the entire wall re-painted quickly with rapid drying, plastic-base, water soluble paint which closely matches the other walls. Connection with the microphone may also be made with silver-print conducting compound, sold in any electronics wholesale house for the repair of printed

circuits. This silver print paint may be applied in a very thin coat, and the conductor lines may be painted over almost immediately after their application. No trace of this installation, if carefully done, will remain. The conductive paint may be run to the nearest moulding and connection there may be made to a twisted pair leading to a drilled pathway out of the room. The two-conductor shielded cable is then connected, as close to the microphone as is practicable.

When the decision is made to leave the wiring exposed, it may be disguised as electrical extension cord, hi-fi loudspeaker wiring, doorbell or thermostat wiring, television lead-in wire or as telephone inside station wiring. The important point here is that the wiring must appear exactly the same as its supposed counterpart and that it be placed in a convincing and realistic manner.

If the walls are papered, it is possible to carefully lift a corner of the paper, near where the wire may be run to cover and to dig out enough of the plaster to conceal the small microphone and its conductors. The paper may be moistened at first, and after the paste softens, gently teased back with a razor blade or thin spatula. After the microphone is installed the paper over the diaphragm area of the microphone should be perforated in several places with a pin so that the sound waves may reach the diaphragm. It is also wise to cushion any microphone bearing on a solid surface with a small blanket of foam plastic or rubber to insulate it from any acoustic shocks transmitted through the walls of the building. Not much is needed. The author has found that a piece of plastic foam sheeting ⅛ inch thick should be carried in the technician's tool kit. Small microphones may also be hidden inside the hollowed rear of a telephone connector block.

With regard to the microphones applied from outside the room, a somewhat different approach is dictated. Here must be considered ordinary microphones, contact microphones and the various tubular microphones. In using the normal microphones, they may be applied by opening the wall of the room adjoining the room under surveillance, carefully hollowing a bit of the plaster and pin-drilling several holes to allow the sound waves to

pass through the wall. The drilling must be done with extreme care or a large piece of plaster may fall away from the surface on the subject's side of the wall. The trick is in allowing the drill to do the work while avoiding excessive pressure on the drill. If access is gained to the room of the subject, the drilling could be done from his side of the wall at the outset and then hollowed on the reverse side when the technician returns to the adjacent room.

Through the use of a contact microphone a similar procedure would be followed, except that it would not be necessary to drill through or hollow out the wall. The microphone is merely retained in close contact with the inner surface of the subject's wall by rubber bands, webbing or tape. The contact microphone may also be cemented, with rapid drying cement, onto a window if the need therefor arises. Indeed, an ordinary microphone may even be held near an open window, if no other opportunity presents itself. Microphones have been affixed to the ends of bamboo fishing rods, the entire assembly spray-painted matte black and held up to an open second-story window or bridged across the space between two adjoining buildings in certain urban areas.

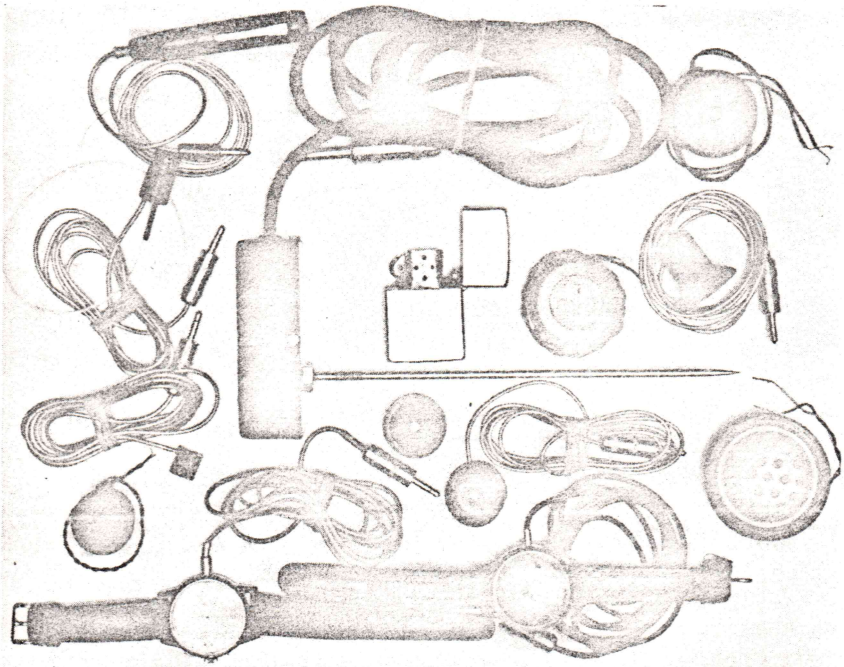
"Spike"-type microphones may be employed in adjoining rooms by drilling a ½-inch hole through the technician's side of the wall and inserting the sharpened end of the spike so that it bears up against the plaster of the exterior of the subject's wall. The microphone, proper, is then supported by tape, webbing or rubber bands thumb-tacked into the technician's side of the wall in such a manner that the armature or "spike" touches no part of the wall except where it bears against the subject's side of the wall. The audio-frequency waves generated within the subject's room will then strike the wall surface, which acts as a diaphragm, and transmit those sounds through the armature to the contact microphone. The contact microphone may also be used, should the opportunity present itself, against the door panels of adjoining rooms. A three- or four-inch spike is indicated in this instance, the spike being detached from the

microphone, driven point-first into the door panel, and the microphone then reattached to the spike.

Tubular microphones may be used against opposing electrical terminal boxes or inserted through previously drilled holes. Models using the 1/16-inch diameter flexible polyethylene tubing may have the tubing inserted through a 1/16-inch hole drilled through the subject's wall. The resulting hole, if at all noticed, appears to the eye to be a finishing nail hole. The exposed end of the plastic tubing should be painted matte black, for ½ inch or so, to reduce the likelihood of discovery. The exposed end of the tubing, of course, should be trimmed so that it is slightly below the surface of the wall. This point should be inspected, if at all possible, from the subject's side of the wall to ensure that the tubing does not protrude into the room. The idea of painting the first ½ inch of the tubing black for concealment purposes has another use—the depth the tubing is inserted in the wall may be gauged by the amount of black still visible from the technician's side of the wall. The tubing, it may be obvious, may also be inserted under the space between a door and the doorjamb, through a keyhole or around the edge of a closed door if the fit is not close. It may also be inserted through available fissures, old nailholes or through a small B-B shot hole made for that purpose through a window. An ordinary microphone may also be positioned over such a B-B shot hole with effective results if it is cushioned with a circle of polyurethane foam. One problem arising with the use of microphones on windows is that ambient noises are transmitted quite efficiently to the microphone along with whatever speech is taking place. It is easily possible that the ambient noise might override the subject's conversation. It is, as a last resort, worth a try, should other techniques prove fruitless.

Wiretaps

The concealment of line tap wiring is somewhat more difficult since it is more often exposed to skilled observation by telephone company service and repair personnel. Either the bridging must be completely invisible, or it must be openly installed to resemble

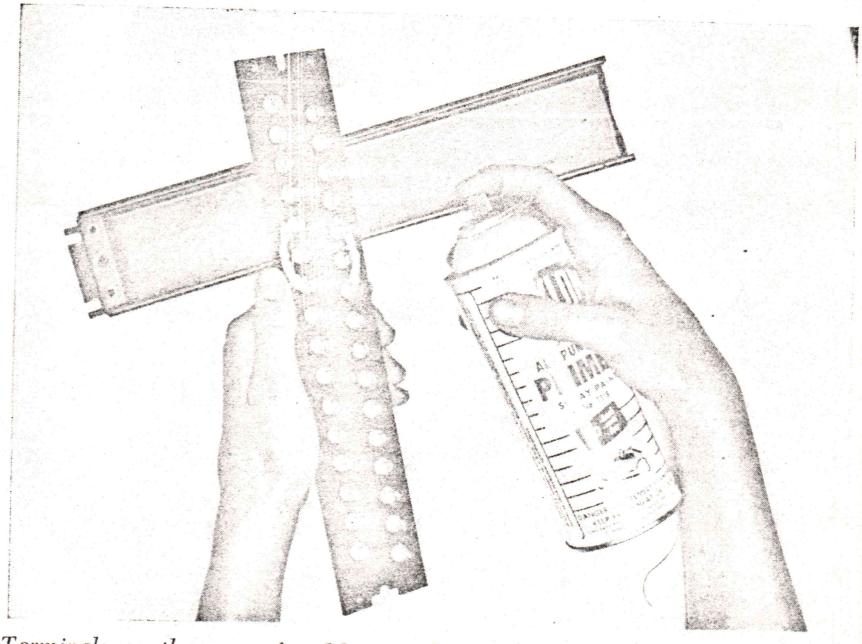


Assortment of microphones used for investigative purposes. Included are two wristwatch models, three dynamic microphones and two magnetic microphones. Also shown are examples of each of the following types of microphones: carbon, suction-cup, spike or vibration, tube, fountain pen and 1½ inch square subminiature magnetic unit.

a normal telephone company installation and meet all of the Bell System Practices (BSP) specifications for careful workmanship. Here it is important that each bit of hardware be identical with that used by the indigenous telephone company. These items, from drop wire through drop wire clamps, insulators, drive hooks, strain insulators and JKT inside station wiring, can be locally procured through telephone company sources or purchased under a cover identity from commercial sources, such as Graybar Electric, or at junkyards dealing in telephone company surplus and scrap. On many occasions, Western Electric Company equipment finds its way onto the surplus electronics market. It is wise to fill stocks when this equipment turns up. Much Western Electric apparatus is sold to the government bearing the WECo

label and often the "Bell System" mark. This equipment may be obtained on the open market through sale of government surplus electronic supplies.

The other alternative is concealment of line tap wiring so that it is not observed by even an astute telephone repairman. For example, in making a bridge at the terminal box, the terminal strip itself may be removed from its protective cover and the bridge made by painting conductors from one pair of binding posts to another on the reverse side of the terminal strip with silver conductive paint, and covering the bridging conductors with quick-drying paint of the appropriate background color. A bridging pathway may also be made with the soft, conductive "lead" of an IBM-type electrographic pencil. Care must be exercised that the bridging conductors thus added do not come into direct contact with the metal body of the protective box lest the line be inadvertently shorted out. Concealed wiring of



Terminals on the rear of a 16-pair telephone terminal board, bridged by the use of silver conducting-paint, being disguised by spray painting over the bridging paths.

this nature may also be added at the protector box, leading to a concealed location where extension wires may be joined to the circuit. Even when requested to physically inspect a subscriber's telephone line for possible "unauthorized connections," as they are called, most repairmen will be too lazy to crawl under a house to inspect every inch of the inside station wiring. Most of them merely shine a flashlight beam under the house and let it go at that if they do not observe anything unusual. Extensions are sometimes added in crawl spaces, difficult to reach, where the connection and extension can be made so that viewing from outside the interior of the crawl space is impossible. For the technician, the more spider webs, refuse and other objectionable matter deposited in the crawl space, the better! Spray cans of artificial spider webs and cobwebs, used in the motion-picture industry, are available from Los Angeles special effects houses. After making almost any kind of installation, this product may be used to prove that "no one could have gotten into that area without disturbing those cobwebs." Another technique employs the use of "dust" made up of talc and powdered charcoal to produce the illusion of an undisturbed area.

A useful method of identifying the binding posts in a terminal box with a particular subscriber's line is to affix to each pair of binding posts a neon lamp in which a 100,000-ohm limiting resistance has been placed in series with one of the leads. The lineman's test set is then connected to one of the pairs (which need not have a lamp connected across it) and the subject's telephone number is dialed. This procedure, it may be pointed out, should be conducted when there is no one present in the premises under surveillance.

The telephone is permitted to ring while the technician listens to the ringing in the receiver of the lineman's test set; at the same time the technician observes the neon lamps. If one of them begins to flutter brightly while the ringing is taking place it is an indication that those terminals to which the neon lamp is affixed are those of the subject's telephone. If none of the neon lamps so flash, it is an indication that none of those terminals

bearing lamps are common with the subject's line. If, on the other hand, a busy signal is heard, it is an indication that the technician may be connected across the subject's telephone line. Should there be no flashing from any of the lamps and the ringing is still heard in the test set, the lamps should be moved to a new group of terminals and this procedure repeated until the subject's line is found.

A faster method, provided that the technician becomes used to the feel of ringing voltage in his hand, is to rapidly run the first and second fingers of one hand down (or across as the case may be) the row of binding posts until a pulsating shock is felt in the fingers corresponding to the ringing heard in the test set.

The neon test lamp may be made by purchasing a dozen or so neon lamps sealed in plastic with a 100,000-ohm resistance sealed in the casing. The type with three- or four-inch insulated wire leads should be selected, and the techician should solder a small alligator clip to the end of each lead. The set may be carried in the technician's installation kit in a small plastic case. Such a set commands a price of from $30.00 to $50.00 from the investigative supply house. It may be made by the technician at a cost of less than $.75 per unit, including the cost of the alligator clips.

It is of the utmost importance to obtain neon lamps with the built-in limiting resistor, because without it the telephone will ring shortly, only once, and the ringing machine will be switched out of the circuit. This is due to the neon lamp ionizing and providing a direct short across the line for the ringing current. The current-limiting resistor prevents this ionization short-circuit.

Quick tap jobs and the use of induction coils and transformers are immediately detectable and should only be used when there is no other alternative or when time is of the essence. They should be removed as soon as is practicable.

Multiple Line Wiretaps

In the event that it is necessary to monitor several incoming lines, it is possible to construct a switching box for the purpose of transferring the lines between recorder inputs. On the other hand, it may be considered desirable to connect each line to its

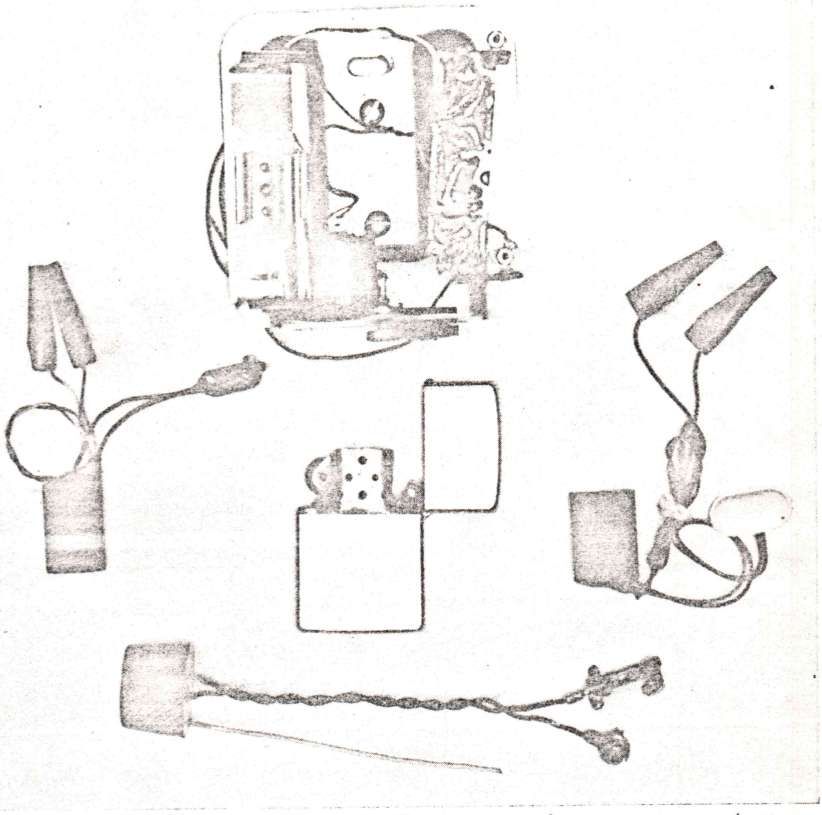
own recorder, so that it may be certain that none of the traffic is missed.

If a switching junction box is used, it may be provided with numbered neon indicating lamps (with built-in 100,000-ohm resistors in series) across each incoming line so that incoming ringing and outgoing dial pulses, each may be observed visually when the line is in use. The switches selected must be of the nonshorting rotary type to prevent crossing one line with another during the switching process. The line matching network may be placed on the recorder side of the selector switch. Another rotary switch may be provided to switch the headset from one line to another independently of the recorder input switch. The headphone switch insertion should be across the line, and a common capacitance may be used in order to prevent charging from occurring on each line when switched in succession. It will prove useful to have a switching box of this type built up and ready for service prior to the time that the need for one should suddenly arise. In all likelihood, a six-position unit would serve the majority of demands for a multiple line monitoring unit.

Radio Transmitters

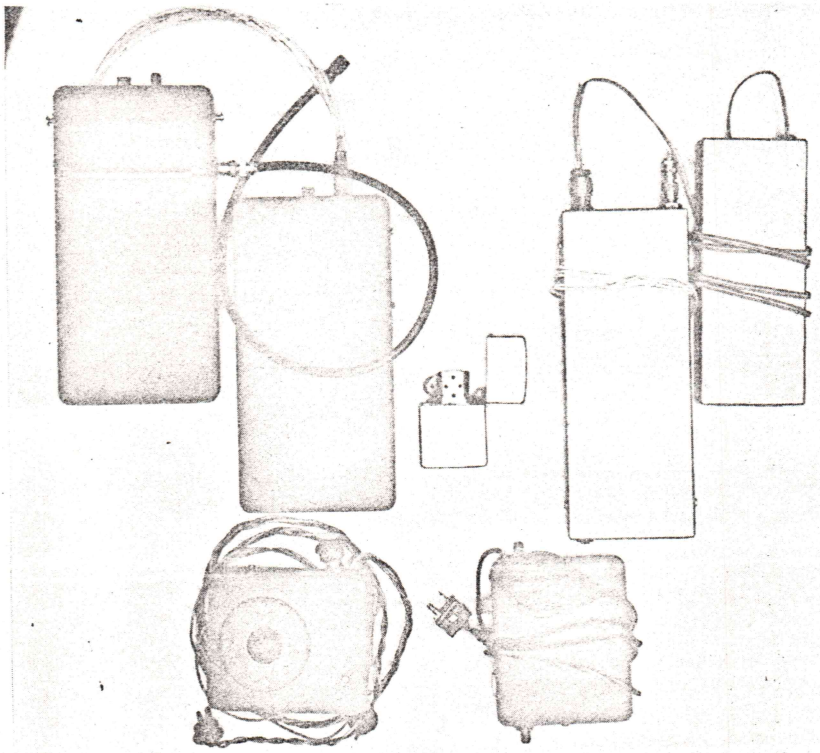
Investigative radio transmitters may be concealed in any object of a size large enough to envelope them. Provision must be made for sound waves to strike the microphone, and the antenna should be extended for optimal operating efficiency. Transmitters have been hidden in dummy telephone sets, functioning telephone sets, cigarette boxes, articles of furniture, picture frames, lamp bases, telephone connector blocks, under rugs, in hollowed-out books and bookends, and in thermostat and intercom housings.

Other concealed transmitters have been hidden in brooms, desk pen sets, paper drinking cup dispensers, inside the heels of shoes and in fountain pen barrels. With the advent of integrated circuits, microcircuits and operational amplifiers, transmitter circuits may, at this time, be concealed in lead pencils, eyeglass frames, clothing buttons, cuff-links, finger rings and tie clasps. This has been enabled by the very recent discovery that



Several telephone line transmitters. All except the bottom unit are battery-powered. The upper unit is concealed in a WECo 305A protector box.

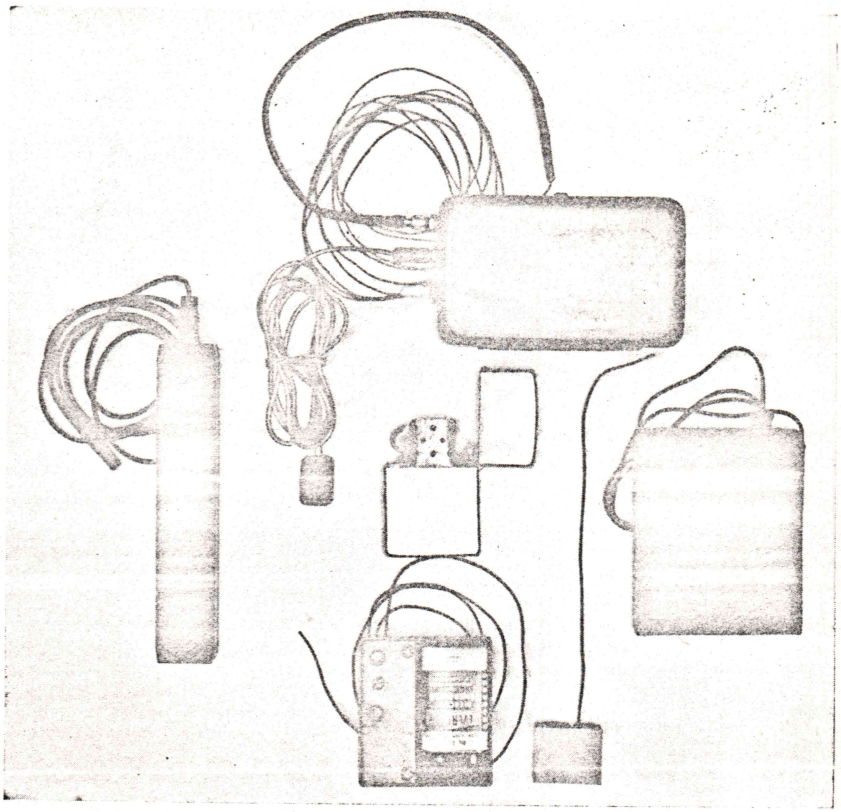
field-effect transistors may be converted to extremely sensitive microphones and by the equally new process of the elimination of the conventional L-C tuned circuit by the capacitive interaction of two micro-chip operational amplifiers. Two of the sub-miniature transmitter's largest components have now been effectively supplanted by truly micro-miniature components. It will not be long before such transmitters will be capable of concealment in such places as contact lenses, false fingernails, and might even be cemented in place in the hairline, eyebrows or in the ear of an agent. They will also have the capability of intradermal implantation, should that be required. Microcircuitry will also



Four vacuum-tube model investigative transmitters. Shown clockwise, from the upper left, is the Mosler Research Products (MRP) pocket transmitter with R-F booster unit; the Fargo transmitter with power supply; the MRP body transmitter designed for operation with a dipole antenna; and the MRP concealable transmitter designed for use with a large external battery supply.

soon produce a complete F-M receiver, capable of receiving the signals from these companion transmitters, which may be concealed in a listener's ear canal.

At the present time, operational equipment is considerably larger and thus more susceptible to discovery. The more stable transmitters may be hidden in various places on the human body or inside items of clothing such as suit and sport coats, topcoats, hats, brassieres and girdles. To ensure adequate range of transmission, the placement of the antenna, of course, is critical. Wire



A selection of transistorized transmitters. The upper unit is used by several clandestine agencies. Notice the smallest unit, which is the size of an airmail postage stamp; it transmits, for short distances, in excess of 24 hours. The other units are low in R-F output but perform satisfactorily for distances up to half a city block under most circumstances. They are characterized by their low cost and the fact that they are virtually untraceable.

tap transmitters are often concealed in the base of telephone sets or in protector or terminal boxes. In some cases they are attached directly to the drop wire or to inside station wiring. One model is concealed inside a case disguised as a standard telephone transmitter, also functioning as such, which may be quickly substituted for the telephone set's original transmitter element. (See circuits at end of chapter.) One other design worthy of note is a transmitter which is connected to the telephone line, preferably inside the base of a telephone set, and functions as a

normal room transmitter, using its own microphone when the telephone is not in use by drawing a small amount of current from the telephone line. As soon as the telephone line circuit is activated, the transmitter *shifts frequency* and transmits the entire telephone conversation. When the call is concluded the transmitter shifts frequency again back to the original frequency and continues to transmit the room conversations. This transmitter occupies a cubic inch of space and may easily be hidden in the base of the telephone set.

DISGUISE OF VEHICLES SELECTION OF EQUIPMENT

Vehicles

Much of electronic audio surveillance operations may be conducted using ordinary automobiles of various types. Radio equipment, monitoring equipment, tools and instruments may all be stored in concealed locations within the vehicle. Any special antennas employed should be disguised or used only on a temporary basis. Equipment, instruments and tools should be carried in suitable carrying cases, such as dispatch cases, brief bags or suitcases of various kinds. In this way the technician may move into an area without arousing undue interest on the part of any curious onlookers.

For certain kinds of operations, special vehicles may be required. Among these may be delivery vans, panel trucks, telephone company installation trucks, telephone company vans or other utility vehicles. Such vehicles may be borrowed from these companies, from used car lots or may be purchased second-hand and re-fitted. Special-color paint formulas are maintained by any large auto body repair shop, so they may duplicate the specially formulated colors characteristic of local utility companies. In addition, the special company decals are ordinarily available at the same source. These decals may also be procured from the company supplying the decals to the utility company. Telephone company sedans, used by executives and inspectors, may also be used. Whenever it is necessary to do any work involving telephone lines or installations, it is recommended that

a telephone company vehicle be parked prominently nearby. Nothing would excite curiosity more than the sight of a workman alighting from a plain automobile, strapping on climbing irons and safety belt taken from the vehicle's trunk and climbing a utility pole to perform his work. The technician must plan every step of his operation, realizing that many people are likely to be observing his activities.

In some cases, it may be less noticeable if the workman appears in an electric company utility vehicle or in a Western Union Telegraph Company truck. It is "obvious" to the onlooker that these workers are in the area to look after power or telegraph lines, whereas the telephone company cover points directly to what they *are* doing.

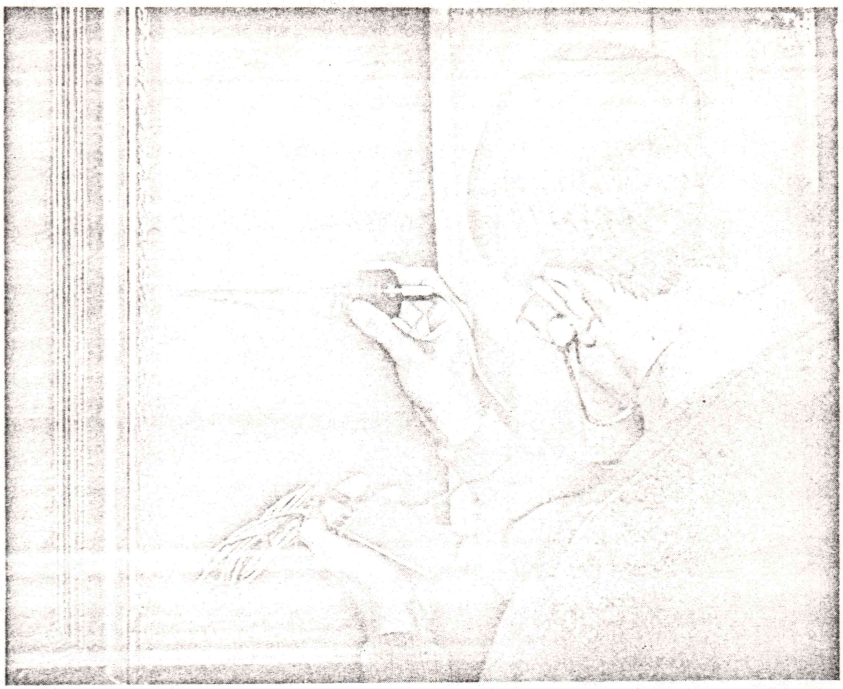
These vehicles may be reasonably parked in a given location for sustained periods, under the pretext that prolonged repair work is being carried on. In this way they may also be used as audio and/or visual surveillance bases.

In van or panel-type trucks, neutral-grey density glass may be reinstalled in the window areas to enhance concealment of observers hidden within the vehicle. This glass is available in three degrees of density and is carried or obtainable through any glass shop. Another advantage of this sort of installation is that photographs may be easily made through it. The glass serves only as a neutral density filter and does not appreciably change the tonal values of the scene. It serves only to block out a given percentage of light—this percentage varying with the density rating of the glass. Another advantage in its use is that all inside the truck appears to be in very heavy shadow, unless a direct beam of light is shined inside. It would not be inappropriate to equip the vehicle also with black drapes, which may be moved over the inside of the "dark" glass, in the event that a curious person shines a flashlight directly into the interior of the vehicle in order to inspect it. A partition, with a doorway, should be provided between the driving compartment and the cargo area in order to ensure concealment. Attention should be directed at equipping the driver's compartment with appropriate safety decals and other impedimenta characteristic of the cover identity of the vehicle. All tools, ladders, wire reels, safety traffic cones,

A suction-cup microphone and transistorized amplifier in use against a picture window. They have been successfully employed through apartment house ceilings and walls with no difficulty.

warning signs and other such gear should be authentic in make and color in order to successfully pass off the deception.

Any monitoring of amplifiers or radio receivers, including communications receivers, should be done at an extremely muted level or with earphones. Many a surveillance has been blown by agents sitting in a parked car, monitoring their local communications channel—for the entire neighborhood to hear. Since almost all of these sets have squelch controls and are silent between



A spike, contact or vibration microphone being used with a hand-held transistorized amplifier through a hole drilled in a wood-veneer wall.

transmissions, it is often easy to forget that they are turned on and perhaps set at a significant volume level.

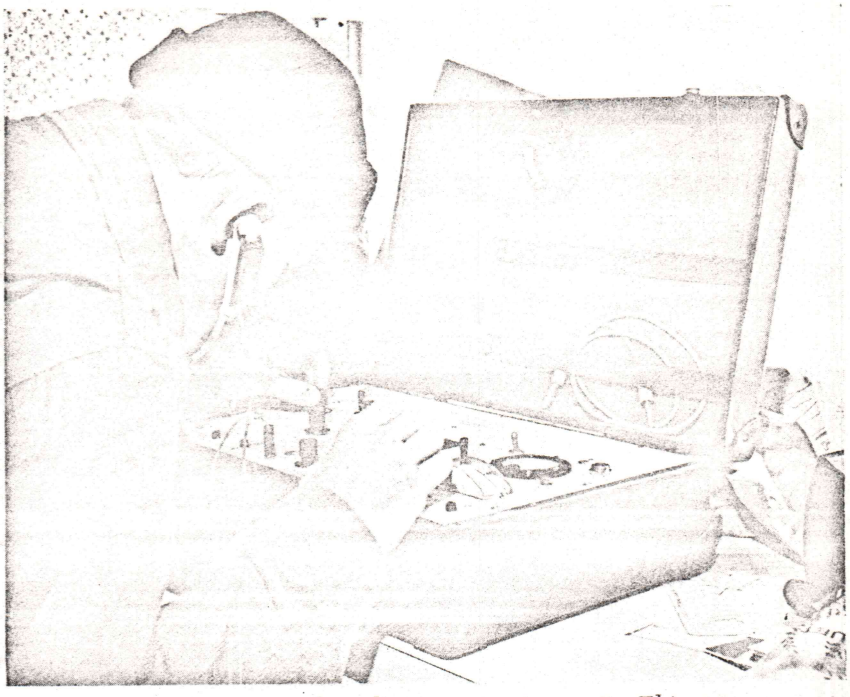
Equipment and Tools

Often needed are extension ladders, a step-ladder, cable reels, a set of pole steps, a detachable ladder platform, canvas tool bags, a supply of drop wire, inside station wiring, drop wire clamps, drive-hooks, strain insulators, a tripod bearing the "Warning—Men and Equipment Working" sign, safety cones and lights, battery-operated flood lamps, elbow-length 600-volt test rubber gloves, a rubber mat, an aerial handline, canvas tool bucket, sets of tool belts with safety straps, pole gaffs, tree gaffs and possibly a small gasoline-engine-driven generator.

All normal hand tools are almost always required. Among these would be numbered lineman's pliers, diagonal-cutting pliers, needle-nose pliers, an electrician's knife, a terminal box wrench, a push-drill with a complete set of bits, a set of adjust-

A form of the tube microphone being used through a wall vent in conjunction with a hand-held transistorized amplifier.

able wrenches, a set of slot and Phillips-head screwdrivers, a hacksaw, a keyhole saw, a brace and bit set along with several eighteen-inch bell-hanger's bits, several drill-saws of various sizes, a roll of "fish-wire," a 50-foot tape rule, an electrician's hammer, a lineman's hammer for starting lag bolts and drive-hooks, a tack hammer for light tacking, a set of wood chisels, cold chisels, both heavy- and light-duty soldering irons, a staple gun, a supply of



Operation of a professional audio investigation unit. This type accepts several microphones of any impedance at the same time as it accepts a wire tap and is equipped with built-in audio rejection filters, preamplifiers, power amplifier and an automatic signal and voice-activated recorder control circuit.

low-temperature solder in paste or tape form and a quantity of plastic electrical tape. Of occasional use is an "Out of Order" sign that can be placed on pay phones, the use of which it is desired to reserve for the investigators.

Instruments recommended would include a good volt-ohm-milliammeter, a lineman's telephone handset, a tone-generator for tracing out lines, a battery-test voltmeter, a tunable field-strength meter for peaking up transmitter antennas, battery-powered pocket-sized preamplifiers, amplifiers and recorders. Other special equipment, tools and instruments would be dictated by the type of operation.

Maximum security must be given to this sort of equipment to screen unauthorized knowledge of its use. Distinctive decals

can be applied to flexible plastic ferromagnetic material and applied to the sides of the vehicles only when they are in use. At other times they may be stored inside, against the steel walls of the vehicle. Special protected, parking and garaging must be provided. Needless to say, these vehicles must never be parked anywhere near the offices of the using agency or near any law enforcement facility. It also stands to reason that their use must be restricted to that for which they were equipped. The tendency to employ them to visit crime scenes, to transport evidence or to serve in some administrative capacity must be denied. In addition, they must be registered "blind" or be equipped with a selection of license registration plates.

Antenna Considerations

Of primary importance in the selection of transmitter antennas is that they must be cut to at least ¼ of the transmitting frequency, if the maximum efficiency of the transmitter is to be realized. Better results may be had by using ⅝ wavelength antenna, if the extra length may be tolerated. In use, the transmitter antenna must be extended as fully as possible, and the antenna sited as high as is practicable from the earth's surface. Transmitters used on the bodies of agents should have their antennas fully extended, in some fashion, through the clothing of the operator. This may be accomplished by making tabs from adhesive tape, affixing them to the antenna and pinning these tabs to reinforced seams or other parts of clothing. If the operator is expected to travel in an automobile while wearing such a body transmitter, the transmission range may be greatly extended by running the radiating portion of the antenna into the sleeve of the operator's clothing most likely to be near a window. Results will be much better if the agent can conveniently ride with his antenna arm leaning out of the window.

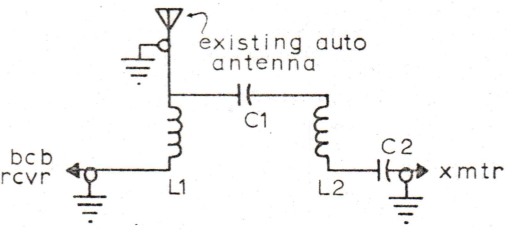
Transmitters hidden in houses may be positioned in the attic portion of the building, with their antennas stapled to the overhead rafters out of sight. From that position, an extension microphone may be run to the room under surveillance. When transmitters are hidden underneath houses, an attempt must be made

to bring the antenna as high as is practicable above ground level.

Transmitter antenna siting is responsible for many of the problems resulting in inefficient operation of these instruments. Another important point is that each transmitter, whenever placed in a new location, must have its r-f amplifier output tank-circuit peak-tuned on location in the place the transmitter will occupy. This procedure is accomplished by the use of a tunable field-strength meter (FSM) and a nylon tuning wand. The FSM is placed near the transmitting antenna, and the transmitter is turned on. The proper band is selected on the FSM, and it is fine-tuned to the operating frequency of the transmitter. This should result in a small scale reading on the FSM. At this point, the nylon tuning wand is inserted into the tank-circuit variable capacitor slot and the capacitor is rotated until a maximum scale deflection is attained in the FSM. A similar process would be followed should the tank-circuit coil be slug-tuned. If the meter goes off-scale, it may be moved farther away from the antenna or its sensitivity control may be decreased, and this tuning process continued until a maximum scale deflection is attained. This will indicate that maximum available power is being delivered to the antenna. If, due to operational necessity, the antenna length must be shortened, its output efficiency will deteriorate greatly. The peaking of the r-f amplifier's output tank then becomes of extreme importance, in order to extract every possible bit of efficiency from an already inefficient, flea-powered circuit.

Automobile installations may be done by hiding the transmitter and its antenna inside the car or by positioning the transmitter in a convenient location so that the antenna will be extended outside of the vehicle. In this case, an extension microphone would be concealed inside the headliner or in some other convenient location. Alternatively, the transmitting antenna may be coupled with an existing broadcast-band antenna by disconnecting the automobile receiver, or by use of a matching network which also serves as a wave trap; such a circuit is shown below:

In this way the subject may continue to receive signals on his broadcast receiver at the same time that the surveillance



100 MHz	50 MHz	27 MHz
L1 - 64 t No. 30, 3/16" form	L1 - same	L1 - same
L2 - 8 t No. 22, " "	L2 - 17 t No. 22, "	L2 - 37 t No. 22, "
C1 - 10 mf	C1 - 14 mf	C1 - 22 mf
C2 - 8 pf	C2 - 12 pf	C2 - 20 pf

Figure 5-1. Broadcast-band automobile antenna adapter for use with a transmitter hidden within the vehicle.

transmitter is coupled to the antenna for transmission purposes. This situation may easily ruin the successful monitoring of speech within the automobile, due to the interference caused by the audio of the broadcast receiver.

A broadcast receiver may also be operated by running a shielded antenna cable outside the underside of the firewall, where the shielding can be terminated, and by looping an insulated straight wire antenna, connected thereto, under the body of the car. Connection of any bare wire portion of the antenna with the body of the car must be avoided. The transmitter may then be coupled to the existing receiving antenna through a shielded lead-in cable. For 30 to 50 MHz transmitters, it is recommended that the antenna be used fully extended. For 80 to 110 MHz transmitters, a height of 36 inches would be suitable. By properly coupling such an antenna and with careful tank-circuit tuning, a 250 mW output transmitter may be made to effectively cover a six to eight square block area in the average flat suburban location. Using the 12-volt automobile supply, with a more powerful unit—say, a two or three-watt output—several square miles may be covered in the same type of area. In desert flat lands, of course, the range will be greatly extended, while in dense, urban areas with high-rise buildings, the coverage would be quite considerably less. Experimentation by the tech-

nician will build a confidence in the capabilities of the equipment he is using, and such experience will enable him to extract the maximum usable power from this type of installation.

With regard to receiver antennas, they are much less critical than the antennas used for transmitters, however an attempt should be made to select and use the best receiving antenna for each installation. When the receiving equipment is to be installed in an automobile, perhaps the best type of antenna is a well-grounded whip, with a loading coil, on the lower frequencies. A disguised broadcast-band antenna, set to $\lambda/4$ may be purchased and used with a matching stub in the coaxial lead-in cable. The exact stub-setting instructions, which vary with the operating frequency, are packed with each of these commercial antennas. It is also possible to use a window-gutter mounted clip bearing the antenna, for hasty installations. One advantage here is that the antenna may be quickly dismounted, leaving no trace of the installation. This is particularly useful with rented or borrowed cars. The receiver antenna, with some loss in efficiency, may also be coupled to an ordinary broadcast band antenna. More efficiency may be obtained if the height of the antenna is adjusted to $\lambda/4$. A straight wire antenna (flung out of the car window) may also be used, although a significant loss in efficiency must be expected.

Receivers utilized inside houses and hotel rooms are best used with a directional $\lambda/2$ dipole antenna, or with a loaded or $\lambda/4$ whip antenna. Lead-in extensions may sometimes be utilized, with the actual antenna placed 10 to 30 feet into the air. A significant increase in signal strength should be realized with this method.

In an emergency, an existing television antenna may be utilized by connecting the 300-ohm twin-lead extension, used by the television set, to the monitor receiver through a 300-ohm: 50-ohm antenna matching transformer.

Communications Monitoring

Whenever an operation is mounted in a particular area or under such conditions that another agency or group might direct or develop an interest in the conduct of the operation, it would

be profitable to monitor the radio frequencies that they have been known to use. This may be done from the plant whether it is in an office, a hotel room or a residence or located in the rear of a van or panel truck. The fact that attention has been drawn to the operation or to the plant is likely to be revealed by the content, amount or type of radio traffic emanating from the net of the monitored group. If operations are being conducted in a limited area, it is easily possible to obtain transistorized six-position crystal-controlled F-M monitors on either public service band and to tune them to an assortment of frequencies likely to be needed in that area. Transistorized variable frequency models are also available with better than 0.7μv sensitivity on the 150 to 175 MHz band and better than 0.3μv sensitivity on the 30 to 50 MHz band. Using the newly developed field-effect transistors, highly-sensitive and stable all-band converters are now marketed with which one may monitor any desired frequency area between 500 kHz and 600 MHz. These converters are available with both crystal control and variable tuning. In some cases private organizations are employing the Citizens Band for two-way communication, and such a sensitive, all-channel transceiver might also be profitably employed. In certain operations diversions may be created to direct attention elsewhere, and the progressive effects of the diversion may be ascertained again by an analysis of prevailing radio traffic. In some cases, information regarding the frequencies in use in a given area are published in a commercial booklet, and in other cases the desired information may be obtained from cooperative electronics or communications personnel. If a physical examination of the mobile units is possible, the frequency band is often indicated by antenna type and length and by the presence or absence of loading coils. This information may also be developed by frequency scanning near a base station.

Voice and Signal Actuators

Through the use of signal and voice-operated relay circuits equipment, such as magnetic tape recorders and video scanning and recording, devices may be actuated by ambient sounds or signals and monitoring personnel need not necessarily be present.

Ordinarily rather simple two-transistor electronic switches, most models contain a built-in time-delay network of the R-C type in order to maintain the device in an "on" position during pauses or lulls in conversation. Time-delay facilities may vary between three and fifteen seconds and are set by varying a potentiometer in the R-C network. In addition, most models employ another potentiometer in a "sound threshold" or sensitivity circuit. By varying this control, the operator may set the instrument so as not to trigger during variations in the ambient noises in the area under surveillance and to begin operation when speech is "heard" by the circuit. Ordinarily their output circuits involve the use of high-resistance coil, plate-circuit, relays or a heavy-duty switching transistor, which closes the motor or power supply circuit of the device controlled. In some cases they are built-in to surveillance equipment, while in others they are used in an "outboard" fashion, through the use of control cables plugged into jacks in the controlled device.

They are made for voice-activation with microphones, signal-operation with radio receivers bearing a squelch circuit and for telephone line activation, set to close when the line voltage drops beyond a certain level.

It is possible for one man to set up a receiver, with voice-activation control, attached to a magnetic sound recorder concealed nearby, to conduct interviews with the knowledge that all of the conversations will (if all goes as it should) be preserved automatically on magnetic tape. Providing the temperature does not rise too high, the equipment may easily be concealed in the trunk of the operative's automobile or in an adjoining room in the case of a motel or office.

At the end of the chapter, several signal and voice relay designs are shown.

Surveillance of Automobiles—RDF Aspects

Discreet surveillance of automobiles is a difficult task at best, and any electronic aid that assists in the task will prove of value. It is possible to install a low-power modulated transmitter in a car and to utilize is signal to aid in pinpointing the location of the vehicle by the use of radio-direction-finding (RDF) tech-

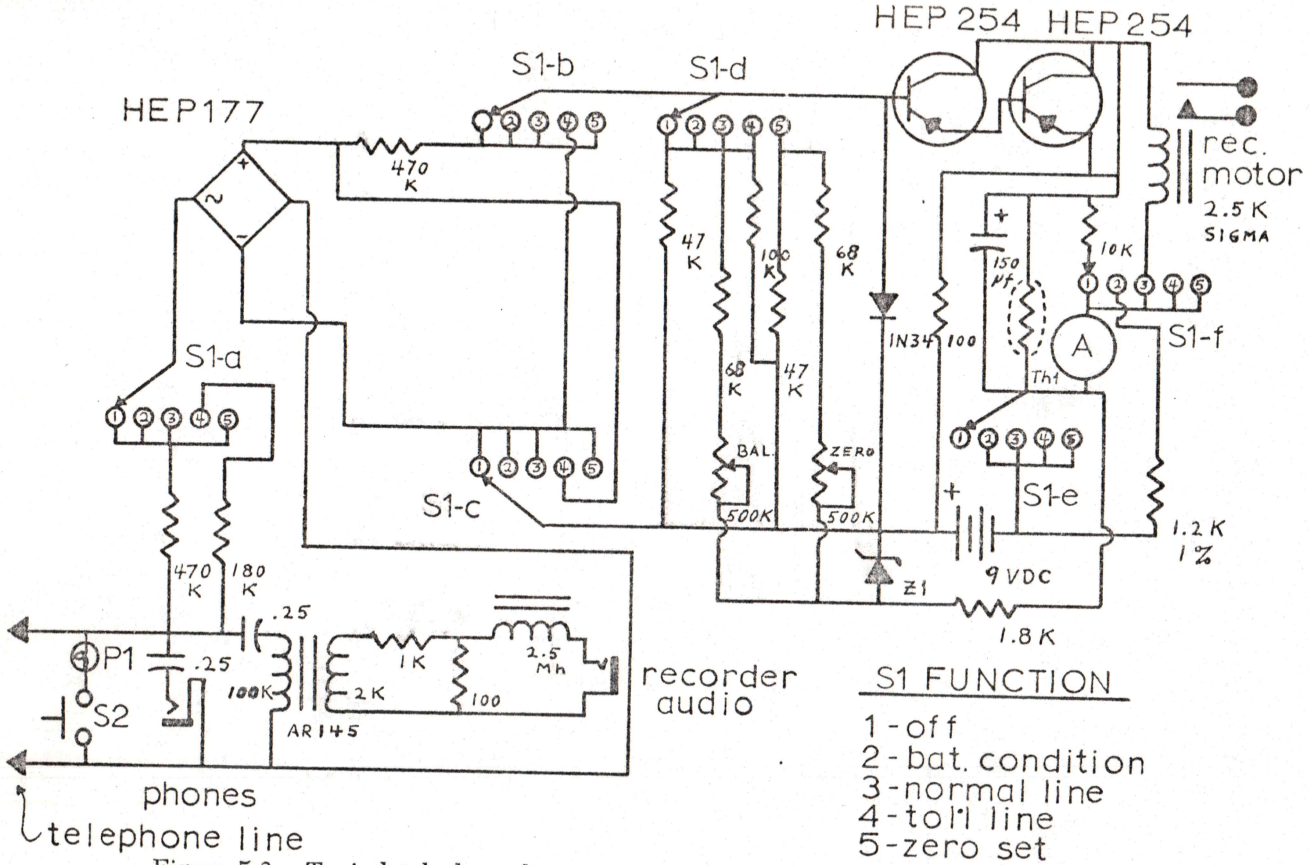


Figure 5-2. Typical telephone line monitor employing a signal-actuatedrecorder control relay.

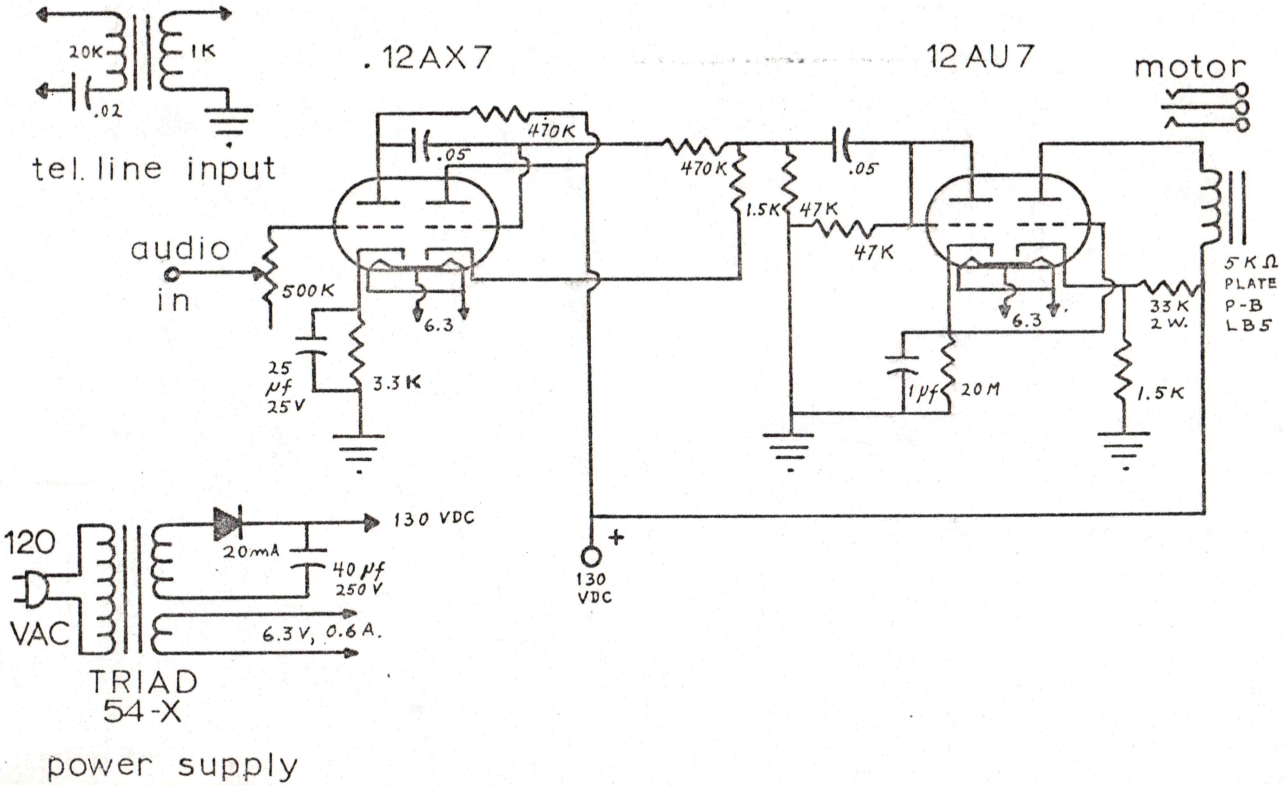


Figure 5-3. Typical audio signal or telephone line control relay (tube).

niques. There are several prerequisites for a transmitter of this type that differ from those used in audio surveillance. The transmitter should be as small as possible and should possess its own power supply which should be capable of operating the transmitter continuously for several days, at least. If the primary supply is 12-volt d-c, the unit may also be powered from the car battery voltage. This, of course, would result in the elimination of the battery life problem. The unit should be provided with its own antenna and should have provisions for utilization of the existing broadcast-band antenna installed on the car. The case of the transmitter may be equipped with powerful Alnico magnets so that it may be quickly affixed to (and removed from) the undercarriage of the automobile.

The transmitter should be tone-modulated so that it is not necessary to employ a receiver with a beat-frequency-oscillator (BFO) to hear the signal. One of the problems arising with the use of higher-powered transmitters is extremely short effective life under full load. This problem has been solved, to some extent, by the development of what is termed a "peak-pulse transmitter." This transmitter, which is also tone-modulated, is circuited with a field-effect transistor "chopper" which turns the transmitter on and off at a rapid rate. On the peak "on" pulses, the effective r-f output reaches the full output capability of the transmitter, while in the "off" cycle its r-f output drops and it consumes little current. The peak r-f output, depending on the design of the transmitter, may vary between 300 mW and 3 watts.

An ordinary surveillance transmitter may be tone-modulated for such purposes by adding a transistorized tone-generator to its audio input circuit. In this way it may be used for normal audio surveillance applications or, by plugging in the audio tone-generator, instantly converted for use in automobile surveillance. The problem of heavy battery current drain, however, will still exist.

Shown in Figures 5-4 through 5-6 are circuits for the peak-pulse transmitter, an effective 27 MHz tone transmitter and a tone-generator circuit which may be added to the microphone input of any surveillance transmitter.

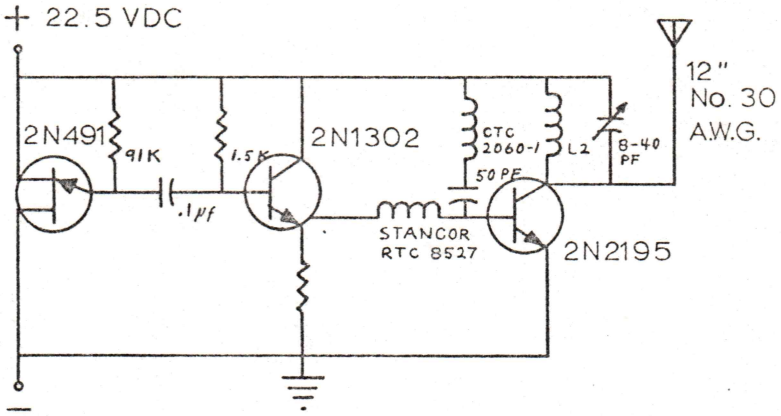


Figure 5-4. Pulse tailing transmitter operating at 50 MHz, employing a tone of 1 kHz/sec with a duration of 50 μsec.

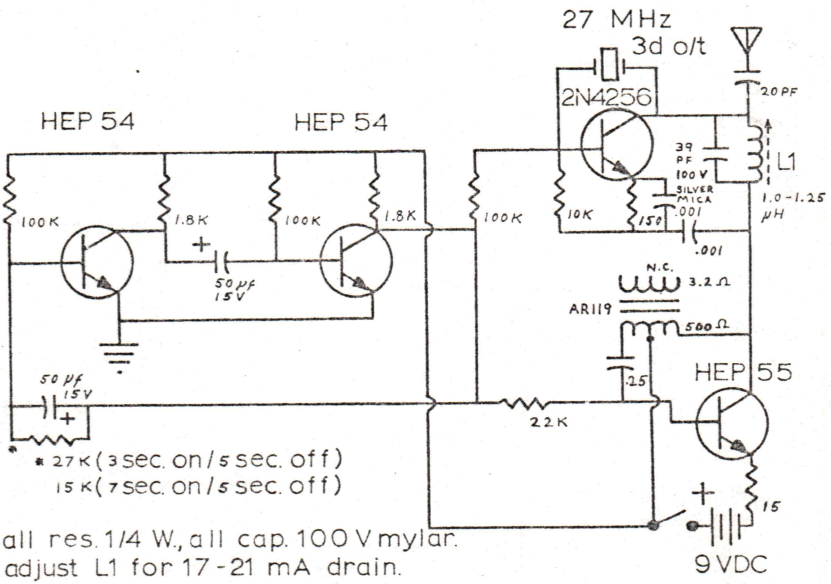


Figure 5-5. Continuous-tone tailing transmitter operating at 27 MHz, with 100 mW output.

Receivers may be modified for automobile surveillance in two ways. On method involves the use of several antennas that may be switched by the operator into the antenna input of the monitor receiver. Selected may be a full $\lambda/4$, and an $\lambda/8$ antenna. The operator may initially monitor with the $\lambda/4$ antenna until the signal begins to "overpower" the receiver, as seen on the "S" meter, or as monitored aurally. The $\lambda/8$ antenna may then be switched in and used until the signal again becomes more intense. Some arrangements include the use of third, even shorter, antenna. When the signal begins to fade it is an indication that either the operator is going away from the subject's vehicle or that the subject's vehicle is lengthening the car-to-car distance. It is possible, of course, that both conditions may be occurring. A sharp decrease in signal strength on the "S" meter or decrease in tone over the loudspeaker may indicate that the subject has changed direction. A more gradual decrease would indicate that the subject may have increased the speed of his vehicle. A sudden increase in "S" units or tone volume would indicate that the subject had stopped his vehicle, whereas a gradual increase would indicate that he was slowing his vehicle. Operating ranges may be as great as up to five miles in certain open areas and correspondingly less in built-up areas. A sudden cessation of the signal may indicate that the subject has found and neutralized the transmitter or that he has driven to a shielded location.

A directional antenna may also be used to indicate the direction from which the subject's transmitter signals are coming. If the directional antenna is not equipped with a switch-in reference antenna, a 180 degree ambiguity will result from reception of the signals from the subject's automobile. The practical effect here is that once the subject makes a turn it may be difficult to ascertain whether it was to the right or to the left. By switching in the reference antenna, it is possible to resolve this direction problem, since a significantly stronger signal will be indicated from one direction, rather than from the opposing direction. Two automobiles, so equipped, may profitably be used by the surveillants in order to keep a running triangulation or "fix" on the subject's automobile transmitter. Two-way radio communication

between the surveillants' cars would be highly desirable. Should the subject's car be "lost," the area may be continuously cross-traversed by both cars until reception is again established. At this point the other surveillance car can be called into the area. At this point both surveillance units may take RDF bearings and plot them in terms of compass degrees on a map of the area. The position of both surveillance units, of course, must be known and marked on the map. Bearings are then taken on the signal from the subject's car by each surveillance monitor and the rough compass bearing is then drawn on the map. When these points and lines are marked on the same map, the lines will converge at some point. The lines' point of convergence on the map should correspond to the approximate location of the subjects' vehicle at the time the readings were taken. This information is best noted in grease pencil on an acetate-protected map mounted on a two-square foot map board. The type of maps provided by oil companies has been found to be of utility. In addition to the grease pencil, the equipment should include a ruled straight-edge, a triangle with both 90- and 45-degree angles and a bow-compass. It is possible to procure a ruled, 180 degree, protractor of approximately eight-inch size, that will substitute for several of these instruments.

It is, of course, possible for one technician to accomplish this triangulation at a greater expense in time and at the risk of losing the subject while the technician is laterally moving his vehicle to a new location to take the second bearing. Where successive triangulations converge or "fix" at different points on the map, it is evident that the subject's vehicle was moved between the taking of the bearings.

Where the fix remains static, the surveillance units may move into the indicated area and conduct a visual search for the vehicle. Increasing "S" unit measurements will result when the surveillance vehicle draws nearer to the transmitter in the subject's automobile. In cases where maximum signal strength is indicated but no sign of the vehicle is observed, the investigators should be alert for the subject's use of an underground or electrically shielded parking area or the possibility of the subject's

car having been placed in a closed garage. At a suitable time, a visual search may be conducted perhaps supplemented by the use of a sensitive field-strength meter tuned to the frequency of the transmitter in the subject's car. When the surveillance is terminated, the transmitter should be unobtrusively removed from the subject's car as soon as possible. This type of surveillance may also be profitably undertaken through the use of fixed or rotary-wing aircraft.

It may be noted that some of the available monitor receivers have not been provided with signal strength meters, nor with any meter indication of received frequency deviation. Included at the chapter's end are examples of simple circuits that may be added to transistorized F-M receivers to provide "S" meter and frequency deviation meter capability. These circuits may be added to the existing chassis and the meters mounted on the receiver's case, or they may be mounted in a separate case, as display meters, and coupled to jacks in the receiver case by shielded cable. The display meter boxes may be provided with magnets so that they may be secured to the dashboard of the surveillance vehicle in full view of the operator.

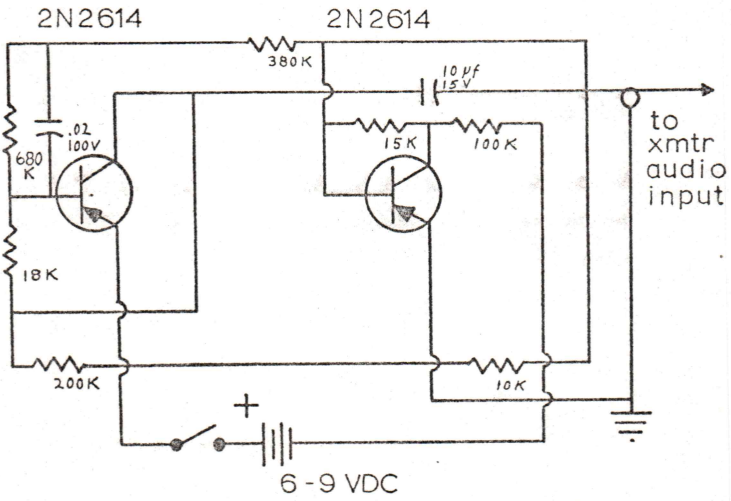


Figure 5-6. Tone oscillator adapter for surveillance transmitter.

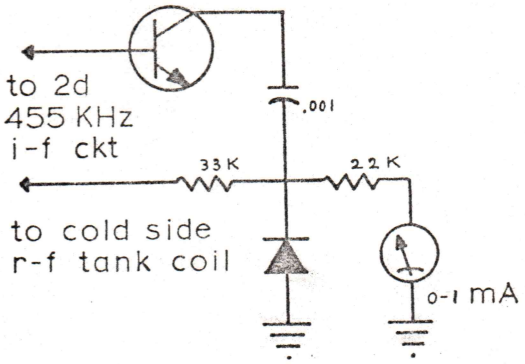


Figure 5-7. Sensitivity ("S") meter circuit which may be added to an existing surveillance receiver.

INVESTIGATIVE APPLICATIONS OF AUDIO SYSTEMS

Microphones

1. Dynamic Microphones. The microphones found in widest application in audio surveillance operations are the dynamic and the magnetic types. Almost exclusively they are of the low-impedance variety, varying between 50 ohms and 1,000 to 2,000 ohms. At one time widespread use was made of a model manufactured by American Microphone Company and designated as the DD-4. This was an adaptation of the active microphone element used in their desk model microphone designated Model D-4. Its impedance was 50 ohms, and it was sold in a matte-finish, black, cylindrical case which measured approximately 1⅝-inches by one inch. American also produced another popular dynamic microphone for investigative use known as the D-801. It was also of 50-ohm impedance, finished in nickel plating and measured approximately 1-5/23 inches by one inch.

Other microphones which have been used extensively are the Shure Model MC-11J, MC-20J and MC-30J series. These microphones are of the controlled reluctance type and are packaged in three models: the MC-11J is cylindrical and measures 1 inch by ½ inch, while the MC-20J and the MC-30J are rectangular models measuring 1 inch by 3/5 inch by ⅓ inch and ½ inch by ½ inch by ¼ inch, respectively. The impedance of these micro-

phones is 1,000 ohms. They are sometimes repackaged by distributors in a black rubber or vinyl plastic case and sold at three to four times their retail cost.

Sennheiser, the German electronics producer, has also sold a large quantity of small magnetic microphones in this country. Most of them are rectangular and the largest measures approximately ¾ inch by ½ inch by ¼ inch. Sennheiser also disguises these microphones in a cuff-link or buttonhole style and a fountain pen. They may also be mounted inside the case of a dummy wristwatch. Some Japanese models have been seen mounted on necktie clips, purporting to be a tie clasp, but their appearance leaves something to be desired.

The United States firm of Knowles and the Tibbetts Company also produce widely-used, high-quality, dynamic microphones of subminiature size.

2. Impedance Matching. In the use of these microphones it is of extreme importance to match the impedance of the microphone with that of the amplifier or recorder or with that of the extension cable employed. For example, a 50-ohm microphone matched to a high-impedance recorder input should have interposed in the circuit a cable transformer with a 50-ohm primary and at least a 50,000-ohm secondary winding. If the 50-ohm microphone is to be matched to a 2,000-ohm input to a transistorized amplifier or recorder, the matching transformer should be 50 to 2,000 ohms. Should it be desirable to interconnect up to 1,500 feet of cable, it would be necessay to use a 50- to 500-ohm transformer at the microphone end of the cable, and a 500- to 2,000-ohm (or 50,000-ohms, in the case of high-impedance amplifiers) at the amplifier input. It has been found that a small, low-impedance loudspeaker will serve admirably for this purpose. The same matching procedure will have to be followed, and the loudspeaker employed may be one that is already present in the room it is desired to place under surveillance. For example, it is possible to utilize the speaker of an existing television receiver, a high-fidelity audio console or that of a table radio. In the case of the speaker in the television set, it is possible to further utilize the antenna lead-in wiring to feed the output of the speaker

outside the house. At this point, it is recommended to disable the television or radio set, so that no interfering sounds will be generated. The advisability of this technique depends on the projected length of the surveillance, the musical listening or television viewing habits of the subject, and the chance that he will immediately seek to have the set repaired. It may be assumed that the repair technician will probably point out to the subject the manner in which the speaker was bypassed, and the fact that the set was disabled. An effective way to disable such a set is to remove one of the tubes and to twist off one of the base pins using a pair of needle-nosed pliers. With a transistor set, one of the leads to the driver may be opened by teasing it loose with a pair of needle-nose pliers. Each of these conditions may be corrected quickly should the need suddenly arise.

Such microphones may be hidden in any of a variety of places within the room. They may be concealed in draperies, behind pictures, in furniture that is unlikely to be moved, in telephone instruments, inside lamps or lamp bases, in wall-mounted electrical applicances or in wall mounted electrical sockets. Microphones may also be disguised as extension electrical cables, with the microphone installed in the socket attached to the end of the cable. The number and variety of places that microphones may be hidden are limited only by the imagination of the technician and the limitations imposed by the physical characteristics of the room.

3. Contact Microphones. Contact-type (also known as "spike") microphones may also be applied to the outside of the interior wall of the room under surveillance. These microphones, which are merely adaptations of crystal or magnetic phonograph pickup cartridges, are enclosed in a shock-mounted audio-insulated case with a pointed-shaft armature which passes through the case and bears upon the sensitive surface of the cartridge. They are used by obtaining a room which adjoins the room under surveillance, drilling a ½ inch hole in the wall of the adjacent room and placing the shaft of the "spike" microphone through the hole so that the sharply pointed end of the shaft bears against the exterior surface of the interior wall of the subject's

room. The microphone case is held in position by a series of rubber bands or tape supported by thumb tacks, so that the shaft does not touch any object other than the subject's wall. The output of this contact microphone is then fed to the amplifier or recorder.

Contact microphones may also be used, without a spike armature, against windows and thin walls and doors. The wall, or window, in each case serves as a diaphragm and transmits to the microphone all of the sound waves generated within the room.

4. Tube Microphones. Small microphones may also be sealed in a sound-proof enclosure with a small rigid or flexible tube being used as the sole source of sound entry to the microphone's diaphragm. These may be made up by the technician or purchased from a law enforcement distributor at three to four times their retail cost. The inside diameter of the tubing may vary between ⅛ inch and 1/16 inch, and either rigid or flexible plastic tubing can be used. The rigid "tube" microphones, as they have been termed, may be used by passing them through electrical outlet boxes which are often located back-to-back in the walls of adjoining rooms. The flexible tube microphones may be used by passing the tube through a crack, under a door or through a false, drilled "nail hole."

These tube microphones may be constructed by the technician by sealing a Shure MC-20 series element into a plastic pill case, after soldering the shielded cable connections and wrapping the sides of the microphone in plastic foam insulation. The tube should be cemented to the face of the microphone element so that the inner diameter of the tubing covers the aperture leading to the microphone's diaphragm. The rest of the space is then poured full of epoxy or casting resin, and the finished product is then sprayed a matte black. This can also be done with the smallest magnetic microphones, placed in subminiature plastic containers, using 1/16 inch diameter flexible polyethylene tubing. The plastic tubing may be as long as 12 inches, but may be trimmed off so as to extend through most double-wall spaces. The end of the plastic tubing should be painted matte black to reduce the visibility of the tubing. For details see below.

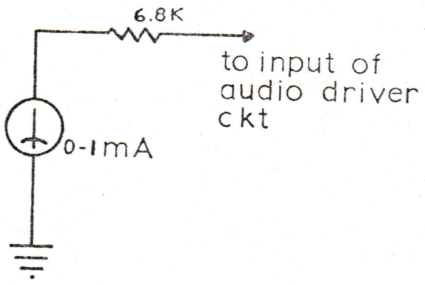


Figure 5-8. Frequency deviation meter circuit which may be added to an existing surveillance receiver.

5. Carbon Microphones. Still of some utility is the ordinary telephone transmitter carbon microphone. These microphones are approximately 200 ohms in impedance, and 2½ inches in diameter. It is also necessary to provide them with a d-c power supply of from 1½ through 6 volts. A matching transformer, with a primary of 200 ohms and a secondary to match either the line or the amplifier, is required. It will be found that this microphone is one of the most sensitive units available, although a tendency toward "carbon hiss" will be noticed. A small capacitance (such as .001μf) placed across the line near the microphone may result in improvement of this condition. One advantage of this kind of microphone is that it may be used, for long distances, if necessary, with almost any kind of unshielded two-conductor wire, or with a single metallic conductor and a ground return. Almost any telephone transmitter microphone in the world can be used. As a point of interest, the telephone receiver unit, itself, may be used as a dynamic microphone in an emergency. A high-gain amplifier would be required.

6. Directional Microphones. A special type of microphone is the directional microphone, which is really nothing more than a sensitive microphone mounted so that only sound waves arriving from a certain direction are permitted to strike its diaphragm. There are parabolic models, "shotgun" models and "machine gun" models—all named after their appearance.

The parabolic reflector microphone is merely a microphone with its diaphragm held at the apex of sound waves reflected

from the surface of a parabolic reflector. The location of the apex, measured perpendicularly from the center of the "dish" reflector, is known as the point of focus of the sound waves. Based on the design of each parabola, at infinity sounds arriving at the reflector reflect and converge at the apex. The distance, perpendicularly, from the center of the parabola to the apex is known as the focal point of the reflector. Experience has shown that these reflectors do operate with a greater efficiency than would be realized with an ordinary microphone, but in general, they have proved unsatisfactory for investigative use. All ambient sound appears to be concentrated at the apex of the parabola and the microphone is not selective in its reception of these sounds. Another problem is that the frequency most efficiently handled by these reflectors is a function of diameter of the reflector. For a parabolic reflector to be most efficient at voice frequencies it should be at least *six feet* in diameter. Reflectors with a diameter of approximately two feet have been sold on the investigative market, and it is here that their great efficiency at reflecting high-frequency sounds has been noted. When used out-of-doors the impact of crickets and other sound-producing insects, along with bird calls and the happy cries of children at play, make a most impossible conglomeration of sounds. Traffic noises also are reproduced quite efficiently. For this reason, coupled with that of its large, unusual shape, the parabolic microphone is perhaps better suited to recording marching bands, bird and animal calls and ambient background noises. It is capable of functioning satisfactorily at close ranges, provided there is low ambient noise and no cross-winds develop between the microphone and the sound source.

The so-called machine gun microphone, which was originally designed by two Western Electric engineers (W. P. Mason and R. N. Marshall) in 1939, consists of a series of ½ inch diameter aluminum tubes each cut two inches shorter than the preceding one, with a maximum length of about 48 inches. It is thus named because it resembles a Gatling gun. The tubes are rolled into a bundle, with the longest tube in the center, and strapped to prevent the bundle from coming apart. The tubing at the microphone end is stacked so that all the ends of the tube faces are

flush. By means of a sound-insulated coupler a very sensitive Western Electric microphone was affixed to the end close to, but not touching, the ends of the tubes. These tubes are cut to resonate each on a separate frequency covering the frequencies ordinarily encountered in the voice range. The formula used to compute the tube lengths is to divide the speed of sound by the frequency and to use one-half of this, in inches, as the length, since an open-ended tube resonates at a wavelength twice as long as its length. Thus

$$L_{(\text{inches})} = \frac{1}{2} \times \frac{1100}{f\,(\text{Hertz})}$$

It is only necessary to utilize enough tubes to cover the practical voice range.

Other models have been built using tubes cut to one-inch difference in length, with an overall length of 38 inches. These microphones have been constructed using both dynamic and crystal microphones and have successfully recorded speech over 250 yards from the microphone. In addition, speech through a *closed window* has been recorded to a range of 50 yards with this microphone. It is necessary to use these microphones with a high-gain amplifier and to aim them critically. Note that the most effective aiming point is not always in line-of-sight with the subject. It has proved most effective to mount them on a pan-head tripod. Cross-winds interfere, as do high-ambient noise levels. Wind noises may be reduced by covering the ends of the tubes with a thin, dark-colored, gauze. The machine gun microphone is particularly effective at close ranges, where it can be concealed from the view of curious onlookers.

The so-called shotgun microphone is merely a slot-loaded version of the tube microphone, generally bearing a single tube-within-a-tube to allow sound waves to reach the microphone's diaphragm. In some cases the outside of the external tube, including the open end, is covered with a one-inch thick coating of resilient plastic foam. Other models bear a resilient plastic foam blanket between the inner, slot-loaded, tube and the external tube. The principle of operation is that only sound waves travelling exactly perpendicularly to the longitudinal axis of the

microphone tube will be able to eventually strike the diaphragm. Sounds entering from other angles will begin to reflect from the inner walls of the tubing and become "lost" in the longitudinal slots provided along the walls of the internal tube. The resilient plastic foam blanket serves to deaden the rigid portions of the microphone, and to allow the use of a high-gain amplifier. Electro-Voice produces a model approximately five feet in length that markets for approximately $1,500, while Sony, a Japanese firm, produces a hand-held model with a pistol grip, several condenser microphones and built-in amplifier for $1,000. The practical limit for extreme range with the Sony is about 250 feet, while the Electro-Voice model is capable of greater range. The Sony is minimal in size, using only a two-foot tube, while the Electro-Voice is approximately five feet in length and four inches in diameter. Caution must be employed with this sort of arrangement because of the unusual character of a crew working with such an eye-catching device.

Microphone Cabling

With regard to cabling of the various kinds of microphones it may be noted that the most critical is the crystal microphone or crystal-contact cartridge. Here no more than 18 to 20 feet of cable may be run between the microphone and the amplifier because of extreme attenuation of the signal and decrease in signal-to-noise ratio encountered with longer runs. Note that only single-conductor shielded cable may be employed. If a preamplifier, however, is used, the cable run may be extended considerably. In addition, the crystal microphone is a high-impedance device and must be matched, by transformer, to any other than a high-impedance input device.

Dynamic, controlled reluctance and magnetic microphones are used with two-conductor shielded cable, and the runs may be as long as 1,500 feet without additional amplification. These low-impedance microphones, of course, must be matched to the 500-ohm cable with line-matching transformers and the line, at the other end, must be similarly matched to the impedance of the input of the amplifier. On very short cable runs, such as less than

50 feet, only the cable must be matched to the amplifier. Line-matching transformers, sealed in epoxy cylinders approximately the size of a lead-pencil eraser, are available from United Transformer Company (UTC). These transformers are relatively expensive ($8 or so), but if high quality and small size are prime considerations their use is recommended. Economy can be effected by the use of inexpensive imported transformers, of the 150 mW size, shielding them with a wrapping of aluminum foil, and sealing them in epoxy in a plastic pill vial. This process serves to shield the transformer from extraneous hum pickup and to render it waterproof, at a savings of $5 on *each unit.*

Cable Noise—R-F Interference

In the running of any microphone cable, especially on long runs, the technician must ensure that the cable is not run parallel to any lines bearing a-c power. If this is inadvertently permitted, considerable hum pickup, induced from the a-c lines, will be encountered. On certain microphone cable runs it may be determined that strong local broadcast radio stations may be heard at the amplifier—often overriding the microphone signal. This situation may be alleviated by carefully grounding (to an earth ground, if possible) the shielding at both ends of the microphone cable run. In addition a small (.001μf) by-pass capacitor may be added, if necessary, between one of the microphone leads and the cable shielding.

If necessary, a No. 32 double-cotton covered wire twisted pair may be used between the microphone and the two-conductor shielded microphone cable, for ease in concealment, as long as not more than approximately 20 feet of this twisted pair is installed. It is recommended that only as much be used as is necessary to effect concealment of the wiring and that the normal two-conductor shielded cable be installed from that point on.

Preamplifiers

In the installation of any microphone it may be desirable, or necessary, to increase the gain of the circuit to a more usable level. This is done by the insertion of preamplifiers in the microphone cable run. The preamplifier may be inserted near

the microphone, near the amplifier or at any point in between. Again, an important consideration is impedance matching. The input impedance of the preamplifier must match the microphone or that of the line, depnding upon the location of its insertion into the circuit. If it is installed at the amplifier end, its input should be 500 ohms to match the line; if it is installed near a 50-ohm microphone, it must have a 50-ohm input; on the other hand, if it is installed midway in the line, it must have both input and output impedances of 500 ohms to match the line. In cases where the preamplifier is at the amplifier, the output of the preamplifier must match the input impedance of the amplifier. This would be high-impedance (say 50,000 to 100,000 ohms) should a vacuum-tube amplifier be used, and 1,000 ohms, or so, should a transistor amplifier be in use.

Any of the small imported two or three-transistor preamplifier circuits sold by the wholesale radio houses would prove suitable and would be quite inexpensive. The prices may vary between $3 and $6 each. The purchase of such items through law enforcement supply houses can easily run ten to twenty times that figure.

Included at the end of the chapter are schematic diagrams of several different useful preamplifiers for adaptation to investigative use. Any of these circuits may be combined in a mixer arrangement to feed their outputs to a common amplifier for the purpose of monitoring several locations and switching from one to the other or of monitoring several microphones situated in the same location, "fading" fom one to the other to select the best intelligibility.

Amplifiers

Serving as the foundation for electronic audio surveillance operations, a reliable, efficient audio amplifier must be selected. Several extremely high-priced (to $300) units will be encountered on the surveillance equipment market place. A reasonable approach to the problem of amplifier selection is to examine those characteristics that are considered necessary in an amplifier of this type and then to examine the characteristics of available component amplifiers and special schematic diagrams.

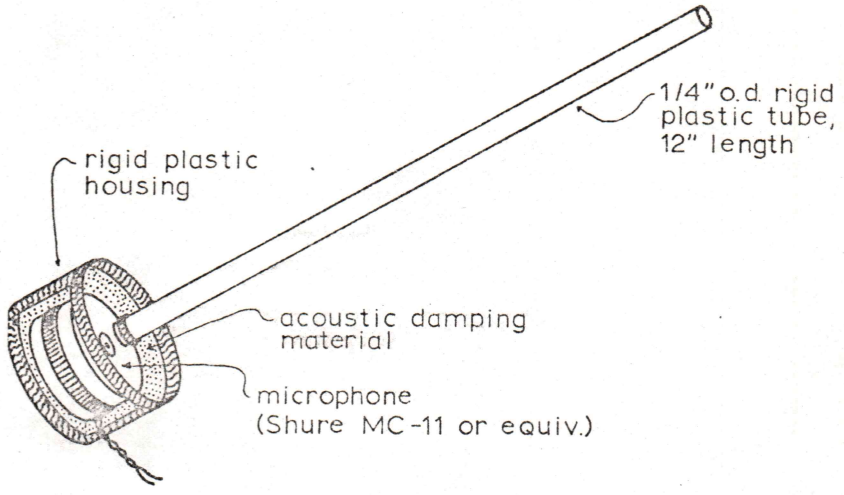


Figure 5-9. Detail of a typical tube microphone.

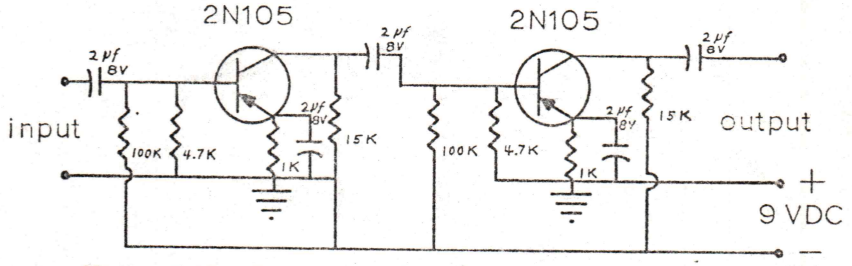


Figure 5-10. Investigative line preamplifier, Lo-Z to Med-Z.

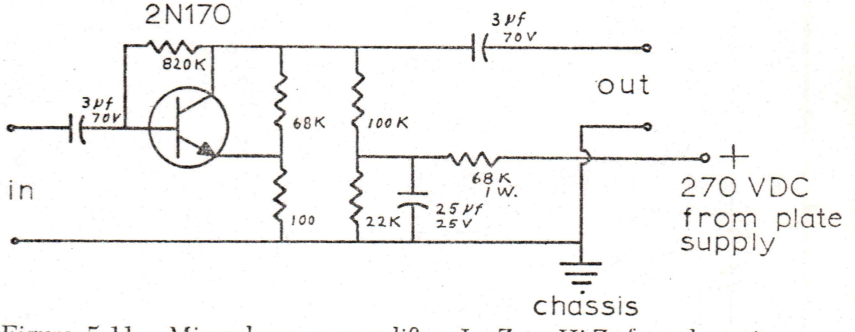


Figure 5-11. Microphone preamplifier, Lo-Z to Hi-Z, for adaptation to a tubed amplifier.

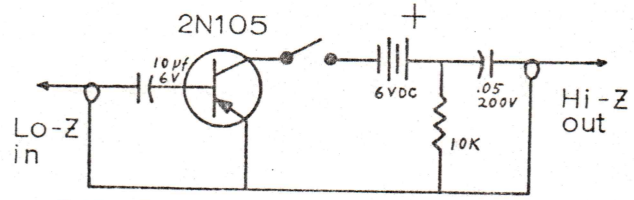


Figure 5-12. Dynamic microphone preamplifier, Lo-Z to Hi-Z.

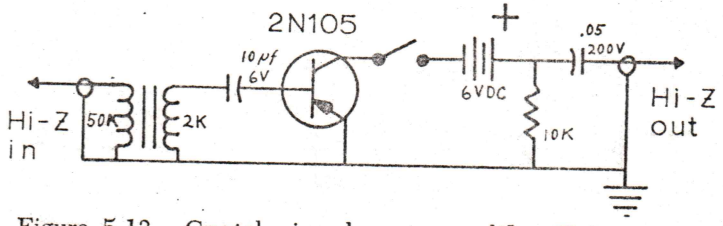


Figure 5-13. Crystal microphone preamplifier, Hi-Z to Hi-Z.

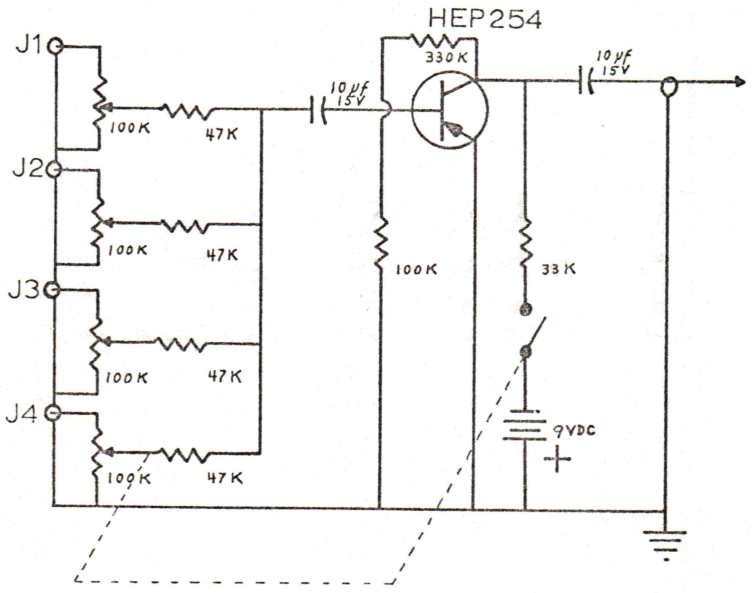


Figure 5-14. Type microphone mixer circuit.

Primarily, the amplifier must be battery-operated, light and easily portable. It should be of small size and should be capable of reproducing voice frequencies with fidelity. The power supply should be operable with easy to locate batteries and should be able to operate from an auxiliary automobile battery. Thus far, it would appear that a good quality 12-volt d-c transistor amplifier with built-in loudspeaker would be indicated.

This amplifier should have both a low-impedance and a high-impedance input and an isolated telephone line monitoring input. Other desirable features would include provisions for headphone monitoring, which cut-out the loudspeaker, a recorder output jack, a gain control (with on-off power switch), a selection of low (8 ohms) impedance and line (500 ohms) impedance outputs. Finally this amplifier should have reasonable gain and an audio output of at least one watt.

A variety of transistor component amplifiers, of both imported and domestic manufacture, are offered for sale by wholesale electronic houses. One of these, which is manufactured in Japan, possesses the following characteristics:

1. Dual input impedance: 50 ohms/500 ohms.
2. Gain control.
3. Separate on-off power switch.
4. Dual output impedance: 8 ohms/500 ohms.
5. Output level of 450 mW.
6. Operates from 9 VDC through 15 VDC.
7. All hum-bucking shielded transformers.

It is offered for sale at less than $8 and can be encased with an additional power amplifier to bring the output level up to a watt or two. It would be wise to add a switch to defeat the power amplifier, if it were not necessary at any point, in order to conserve the battery supply. In addition, a small loudspeaker would be needed, along with the installation of jacks for multiple inputs and the recorder and headphone jacks. The addition of a simple telephone line monitoring isolation and matching network would complete this "ideal" general purpose investigative amplifier. The two-watt power amplifier could be provided at a

cost of approximately $7, bringing the total cost to under $20.

Shown in Figure 5-15 is the circuit of this preamplifier. Also see the sensitive all-silicon transistor, general-purpose investigative amplifier circuit shown in Chapter 2. The technician will realize that the input and output circuits of almost any amplifier may be altered and that the use of preamplifiers to feed power amplifiers is indicated for investigative applications. If necessary, these circuits may be purchased on-the-spot in wholesale electronics houses in any large city, should the technician be caught without any of his special equipment on hand. This situation may also be appreciated should the technician be required to travel "light" through Customs or through any other checkpoints where it would be inadvisable to arrive bearing quantities of what may be easily recognized as "bugging" equipment.

Sound Recorders

Any magnetic tape recorder may be adapted for investigative use by addition of one or more of several simple circuits designed to alter the input impedance, the input type, the input signal level and to add the capability of automatic gain control (AGC) and voice or signal actuation.

Inputs may be altered by matching line transformers or by the insertion of supplementary preamplifiers. If the tape recorder's amplifier has a 2,000-ohm input, and it is desired to use a 50-ohm dynamic microphone to avoid impedance mis-match losses, it will be necessary to employ an audio transformer with a primary winding of 50 ohms and a secondary winding of 2,000 ohms. If it is planned to use a block or more of two-conductor shielded 600-ohm microphone cable with that 50-ohm microphone, it will be necessary to use a 50-ohm:600-ohm transformer at the microphone and a 600-ohm:2,000-ohm transformer at the recorder in order to prevent excessive losses and line noise. In many cases, it will be necessary to give a "boost" to the signal, and a supplementary amplifier may be inserted in the line or at either the microphone or the recorder. Separate power supply circuits are used with the 200-ohm carbon microphone circuits, and it is not necessary to employ shielded cable. Carbon micro-

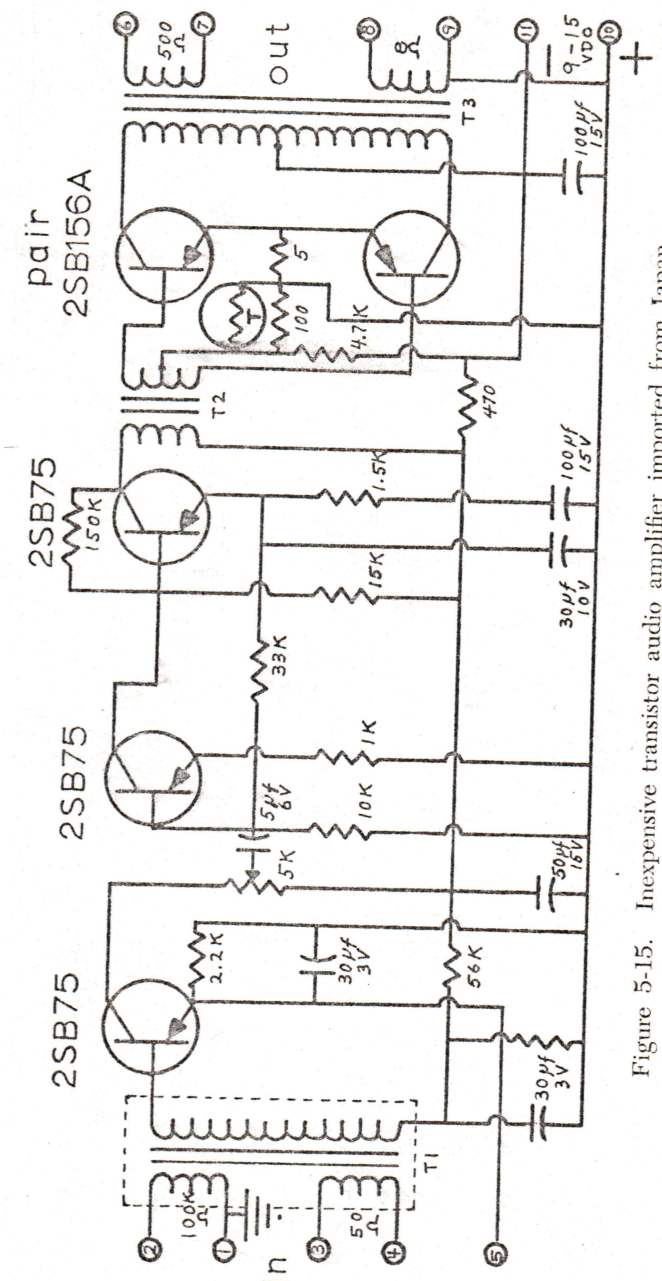


Figure 5-15. Inexpensive transistor audio amplifier imported from Japan.

phone circuits have been made where one side of the microphone was connected to a good earth ground, and the other conductor utilized was a single strand of a barbed-wire fence that happened to be placed in a fortuitous location.

Telephone line inputs may be adapted by simple matching transformer isolation supplemented by d-c blocking capacitors which serve to block out the d-c component of the pulsating d-c signal. Inductances are sometimes added to filter out interfering radio frequency signals which may be unintentionally picked up by the apparatus. In most cases no additional amplification is needed in this type of circuit, but if required, transistorized amplifiers may be inserted.

Signal or voice-actuated circuits may be added for economical monitoring. These circuits may be used with microphones, telephone line inputs or radio receivers. In the case of their use with radio receivers they are sometimes known as carrier-operated relays. The microphone models may be termed "voice-operated" relays, and the telephone line variety may be known as voltage-activated relays or telephone "triggers."

Audio mixers are often used in conjunction with microphones in several rooms, or with several microphones in the same room, to best blend in the conversation it is desired to record. Some mixers also contain amplifiers so that the audio gain may be independently varied.

Shown also at the end of this chapter are several circuits that have been found useful in the field. Certain circuits have been "taken-off" from bugging instruments utilized for illicit purposes.

TELEPHONE LINE MONITORING

Installing the Wiretap

The basic equipment required to monitor any telephone line is simple, indeed. Needed only is an earphone or headset, in series with a small capacitance (between .02μf and .01μf) and a convenient location along the telephone line to be monitored in which to attach the headset across (in parallel) the line. To avoid excessive voltage drop in the monitored circuit a resistance

may also be added in series with the headset. In order to make an adaptation for sound recording, the line must be matched to the input of the recorder or amplifier and must be isolated from the telephone line. The matching transformer should have a 10 to 20 K Ω primary and the secondary should match the impedance of the input of the recorder or amplifier. The isolation is provided by one or a pair of .02 mfd capacitors rated at least 600 volts and small bypass capacitors from each side of the line to the chassis ground. To reduce induced radio signals, a small .001 mfd capacitor may be placed across the secondary leads of the transformer, and r-f chokes placed in series in the primary circuit. Figure 5-16 shows a diagram of a typical device.

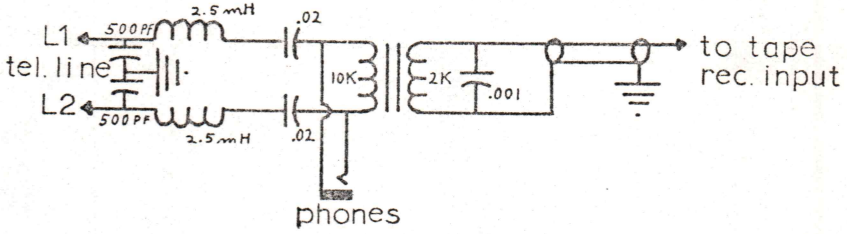


Figure 5-16. Isolated telephone line matching network.

The line may be monitored at any point between one telephone, through the central office, to the other telephone in the circuit. The connection point may be at the telephone instrument's connector block, along the station wiring, at the protector box, along the drop wire to the pole, at the nearest terminal box or at subsequent terminal boxes nearer the central office. Sometimes a pair of extension wires are run off the connection point to a location where the tap may be conducted discreetly. This may amount to a pair leading to an empty house or building, a buried pair leading to a convenient location or merely a pair running down the side of the pole into the ground. The monitoring may take place inside a van-type truck through concealed terminals connected after the vehicle is parked. These terminals may be of the quick-disconnect type so that, if surprised, the operators

might proceed to drive away without even alighting from the truck to sever the connection.

If the monitoring is to take place in an apartment house the terminals of the telephone to be observed may be bridged with an unused pair in the apartment house terminal box or with the terminals of an existing telephone in the apartment used by the monitoring agents.

Routine Installations

When the subscriber's pair leaves his premises, it goes next to a terminal box located nearby. This box may be on a pole, on the wall or in the basement of a building. The pair is connected there to a numbered pair of binding posts (b.p.) labeled with the pair number or in some cases only every fifth pair of binding posts bears a number (five digits apart). The pair, along with several other pairs, leaves this terminal box and proceeds to another, larger box known as a "B" terminal box or bridging point. Here, again, they are numbered, with only every fifth binding post bearing a number, five digits removed from the previously numbered binding post. When leaving the "B" box the pairs are enclosed in cable, bearing up to 600 pairs, for transmission to the central office. This cable may be aerial or at some point it may go underground. This cable is often run to a second "B" box, or bridging point, where the pairs make a second "appearance" on numbered binding posts. Here they are usually run together with many other additional pairs and encabled further enroute to the central office. It is not uncommon for a pair to make an appearance at five or six "B" boxes before it terminates at the central office. Some of the cable is sealed in lead sheath, which is filled with nitrogen under pressure. Pressure alarms located at test desks signal switchmen when gas pressure drops in a given cable. The larger cable may bear as many as 2,120 pairs.

In the Cable Records Office of a telephone exchange is kept a line card on each subscriber; on this card is shown his telephone number, the number of his cable and his pair numbers, and the physical location of each "B" box or bridging point where his pair makes an appearance between the central office and the

subscriber's telephone location. These bridging points may be learned by bluffing the information out of the exchange repair clerk, by posing as a repairman or installer, or by personal contacts within the telephone company. It is possible to learn the special number of the Cable Records Office, or name of the exchange repair clerk, and call posing as a repairman. Using the cover of checking trouble on a particular subscriber's line, the tapper relates the number to the repair clerk, asking for the pair and cable numbers. When given these, he next calls the Cable Records Office and asks for the "B" boxes or bridging points of the appropriate pair. In order to be successful using this cover, as with other cover deceptions, the operator must be letter-perfect in his knowledge and use of telephone company terms in the area in which he is operating. On the West Coast these points are known as "B" boxes, in the Washington, D.C., area as "multiples," in New York City as "bridging heads." In other areas they are termed "appearances." With the information obtained from the cable records clerk the operator now knows the exact points that the desired pair appears—both aerial and underground. Each of these locations may then be inspected from the standpoint of selecting the one location that offers the maximum ease in establishing the surveillance "plant." The operator would look for an unused apartment, building or house in the close vicinity of the appearance or for a "B" box in an outlying location where his presence during the required times would not normally arouse suspicion. An extension drop wire is then strung from the terminal box to the plant, using telephone company drop wire, clamps and drive hooks, in the approved Bell System Practices (B.S.P.) manner. Any departure from approved B.S.P. standards of workmanship would be likely to arouse suspicion from even the newest installer, since conformance to these specifications is forcefully impressed upon him from the time he begins to work for the company.

Apartments, Hotels and Office Buildings

The procedure for monitoring apartment, hotel and office building telephones is rather more simple. In apartment houses and office buildings, provided that an apartment or space can

be secured in the building, the subscriber's line is merely bridged with an agent's apartment or office telephone binding posts. These terminal boxes are usually located in the basement. New construction practices in apartment houses consists of running a single cable, containing all of the pairs appearing in the apartment house, through at least one room of each apartment in the building. In this way is the installation of a new telephone service for a subscriber simplified. The installer merely opens the connector block in the wall of the room bearing the cable, identifies the correct color-coded pair and attaches a new connector block for the subscriber. Extension telephones may be added by running inside station wiring from that connector block to the desired rooms. Routine color codes may be found at the end of this chapter. For the wiretapper it is just as easy. It is not even necessary for him to add any additional wire. He merely identifies the color-coded pair assigned to the subject of the surveillance in the newly rented plant and makes the physical connection. Identification may be made simply by placing an audio tone on the subject's binding posts in the terminal box and checking the other pairs in the cable until the proper pair is found. Alternatively, note may be made of the color-coding of the subject's pair when examining the terminal box in the basement. The proper pair will be found in the cable which travels throughout each apartment.

In hotels, all of the pairs from each floor usually terminate in a "house box" on the wall in the hallway of the same floor. If a room can be obtained on the same floor as the subject, the operator merely bridges the binding posts of the subject's room telephone with those of his own. In the house box each pair is usually tagged by room number. When working in the basements of hotels, apartments and office buildings, the operator must be prepared to pass the scrutiny of any workers or officials he is likely to meet. The telephone company repairman cover is usually best, but the operator must be prepared to properly document himself. In addition, his dress, language, deportment and tools must round out the cover. Bribery of building employees has been done but, as in other cases, is fraught with many dangers.

In order that no interference is created when the operator first attaches his equipment, it is desirable that the telephone line be free from use. This situation may be tested by clipping one lead of the test set to one of the binding posts and by holding the other clip between the thumb and forefinger of one hand. The operator moistens the forefinger with saliva and then slides the alligator clip into the wet area about an inch from the fingertip. The fingertip is then touched to the other binding post of the desired pair. If a conversation is in progress the call will be heard faintly in the earphone and connection can be forestalled. It is also possible to slowly slide the clip closer along the moistened area of the finger to the binding post, while capacitor in the handset is forming. When the clip actually touches the post the capacitor will be fully-formed and the connection will be made noiselessly.

Tracing the Drop

The knowledge of subscriber's telephone number presents another problem which can be solved easily by the experienced operative. The types of subscribers' numbers, found in the majority of telephone companies, are shown below:

1. *Listed numbers*—those shown in the directory.
2. *Unlisted numbers*—eligible but not yet published in the directory.
3. *Nonpublished numbers*—those numbers treated as confidential by the telephone company.
4. *Special nonpublished numbers*—those numbers treated by the telephone company with the greatest of security.

Obviously, there is no problem with the listed and the unlisted numbers; information about the others is obtainable by the expert technician. By tracing the subscriber's drop wire from his telephone to the nearest "B" box the pair number can be obtained. The cable records clerk may then be queried as to the unknown subscriber's name, address and drop number. In the case of the special nonpublished number, the pair is traced back to the nearest cable. At this box the cable number is obtained and the cable records clerk is queried with the cable number, the

unknown pair number, and six to ten *other* pair numbers. The operative requests the drop numbers of all the pairs; he is usually given this information because even special nonpublished numbers are not tagged in the Cable Records Office. In some areas of the United States a new development in circuitry has been initiated to aid repairmen and splicers to identify *any* unknown pair. The test set is merely connected to the unknown pair and a special test number is dialed. A recorded voice then is fed into the previously unidentified pair, at the central office, verbally stating the subscriber's number. This system will eventually be used in all major urban central offices.

Identifying Called Numbers

Historically, the early technicians could determine the number the subject was calling by listening as he gave the operator the called number. With the advent of automatic dial central offices, a new problem was created. A stop-gap procedure was for the wiretapper to short the line momentarily during the dialing process. This would cause the caller to obtain either a "wrong number" or no response at all to his call. When this process was repeated several times, the caller would become exasperated, dial the operator for an operator assist and give the desired number orally to the operator who would then dial the number for the subject. When automatically activated recorders are attached to the telephone line, the dialed number may be obtained by playing back the recorded tape at the next slower speed. Also utilized may be a dial impulse recorder or "pen register." Early models of these instruments, manufactured for the Bell System by Foote-Pierson or Kearfott Manufacturing Company, consisted of a set of electromagnets, mounted on a base in conjunction with a spring-wound paper tape drive, which were placed in series with the subscriber's pair. The armature of the electomagnet, which snapped downward with each closing of the dial switch, served two functions: the first was to press down the moving ½-inch wide paper tape against an ink pad and the second was to release a pawl allowing the spring-wound tape motor to pull the paper tape across the inking area. Thus, with each impulse-digit dialed

by the subscriber to whose line this device was affixed, would appear on the paper tape a short ink mark. The entire number dialed by the subscriber would appear on a length of tape—a series of dashes separated by spaces. Figure 5-17 is a representation of a section of such a tape, bearing the digits three and four.

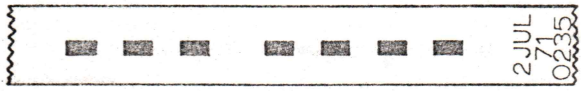


Figure 5-17. Paper strip from a telephone dial impulse recorder showing several digits and the date/time stamp.

A zero, of course, would be represented by a series of ten digits. The instrument had a time-delay built into the circuit so that it would turn itself off several seconds after the last digit of the number was dialed. An optional feature, obtainable with this model, was a built-in date/time stamp which automatically stamped the date/time group once on each set of dialed digits. These devices were originally used by the telephone company to check on the accuracy of their billing procedure for long-distance toll calls. They were used in the main distribution frames (MDF) or at the Test Desk. Immediate adaptation of these instruments was made for investigative use. The pen register was mounted in a leather dispatch case, along with a battery-operated audio frequency amplifier and a telephone line matching network. Many were purchased by governmental agencies and they may still be found in use today, although International Telephone and Telegraph's (ITT) Mackay Marine Division produces a transistorized, all-electronic version weighing less than eleven pounds, using no relays or solenoids, and which presents an extremely high-impedance to the line under observation. This device also prints a series of digits on paper tape but does it electrically, avoiding the use of ink or ballpoint pens. In addition, the dial impulse recorder provides for actuation of a magnetic tape recorder and is available with the date/time stamp feature. Models are also produced to operate on tone-signal dial systems; however, they are not compatible with the dial pulse systems.

Sources

Once the called number is obtained the technician obtains the information regarding the called subscriber from the telephone company. If the requestor represents a law enforcement agency, the information is forthcoming through a liaison with a telephone company special agent. If no official connection (or interest) is desired the information may be obtained through cooperative installers, repairmen, switchmen, female clerks, or other, previously developed, company officials. In certain cases, it must be remembered, telephone company employees (including the special agents) are possessed of loyalties which surpass even the boundaries of the company. They have been known to inform surveillance subjects regarding the investigative interest in their telephone lines. Company rules, it should be remarked, prohibit any sort of activity departing from the providing of normal communications service and require the employee to report to his supervisor any evidence he may find of attempts at line observation. From this standpoint the astute investigator will avoid unnecessary contact with telephone company personnel. Many telephone company special agents are former government agents themselves and provide "effective liaison" with the Bureau, although consistent with policy within the Bureau, they are given little information concerning subjects of investigative interest.

The Discreet Drop Trace

Using audio or supersonic tone oscillators, it is possible for the technician to avoid contact entirely with telephone company employees. These devices are placed across the line, generating a unique, easily recognizable tone and traced by the technician to the "B" box both removed from the subject's location and having easy access to premises in which to set up the plant. This process may be done quickly, in broad daylight or in the quiet hours, by a team of technicians utilizing two-way radio units. The oscillator is installed by the first man at the terminal box nearest the subject while the other is already up the pole bearing the nearest "B" box with his tone detector set. As soon as the second technician locates the proper binding posts he marks

them and contacts the first man by radio transmitter to remove the oscillator and immediately clear the subject's area. From there on the subject's line may be traced as far back to the central office as may be required. The process may be done by one man, necessitating longer time with the tone generator in service. Such circuits are shown at the end of this chapter. Ordinarily, all of these techniques may be unlawful, when applied under a given set of circumstances, and this must be borne in mind by the personnel conducting the surveillance.

Use of Leased Lines—Special Service Lines

Under certain conditions the telephone company will lease a telephone line to anyone. This line, specially tagged, which might begin at any location and terminate at any other location, is left unconnected at each end and is leased to the subscriber for so many dollars per mile per month. Routinely in the past, they have not been concerned about what external connections the subscriber might make to these lines as long as the safety limits of voltage and current are met. While the technique has been used by many other investigators, it has also proved a great favorite with the FBI (as revealed by many of their "blown" cases), who have the lines terminate in one of their offices or in the office of a "dummy" cover organization. Once installed, the investigator may connect a hidden microphone and amplifier to the leased line or make direct connections to the telephone lines of other subscribers. A team of agents is then stationed in the plant to conduct the monitoring and recording process during the appropriate hours. Their participation in a series of unlawful bugging incidents in the State of Nevada was widely publicized in 1967 when the Nevada Governor attempted to charge local FBI representatives with conspiracy to violate invasion of privacy statutes. The case, it may be noted (and which had been predicted), died a natural death. The microphones had been planted in the offices of notorious underworld gambling figures who were alleged to be "skimming off" gambling profits before federal and state taxes were levied. There are those who believe that these same Mafia overlords are bound closely with the

existing political structure in that State. This view is not surprising when compared with similar situations in other states in which crimino-political linking is generally recognized, although documentation (it will be appreciated by the reader) is difficult, at best.

Capacitive and Inductive Coupling

Other means of monitoring telephone lines include observation by induction and by capacitive-coupling. In the induction method a small coil of copper wire wrapped around a ferromagnetic core is brought into close conjunction with any of the existing circuit coils to inductively pick up the magnetic fields of force surrounding these coils when they are energized by the completion of talking circuits. Any single-party extension telephone, bearing a functioning ringer circuit, may also be used to monitor the main line by inductively coupling to the *ringer coil* with an extremely sensitive amplifier and coil. It is not necessary to actually make a physical connection to the line, and the induction coil may also be used along the drop by separating the pair and inserting the induction coil between the wires of the pair. Better results are obtained if one of the conductors can be looped around the inductance. This procedure is quite feasible without destroying the insulation of the pair on the open wiring or twisted-pair found in areas of the open country. Induction coils will pick up any electrical field, nonselectively, and are thus quite efficient electrical noise detectors. Regardless of what some manufacturers claim, induction coils are usable no more than a few feet from a telephone instrument. Figure 5-18 is a diagram of inductive-coupling to a pair.

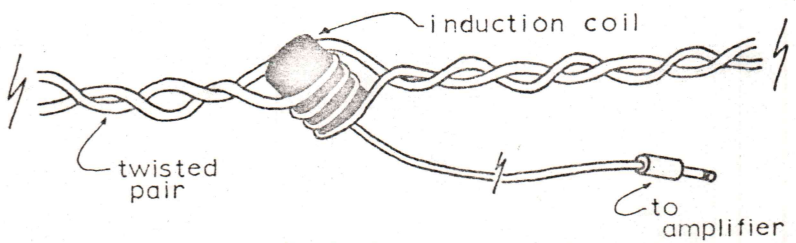


Figure 5-18. Example of inductive-coupling to telephone line.

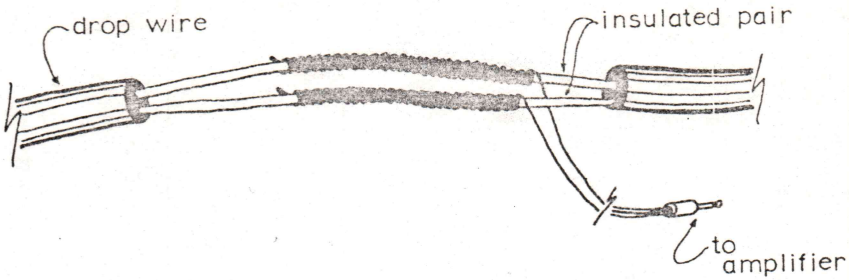
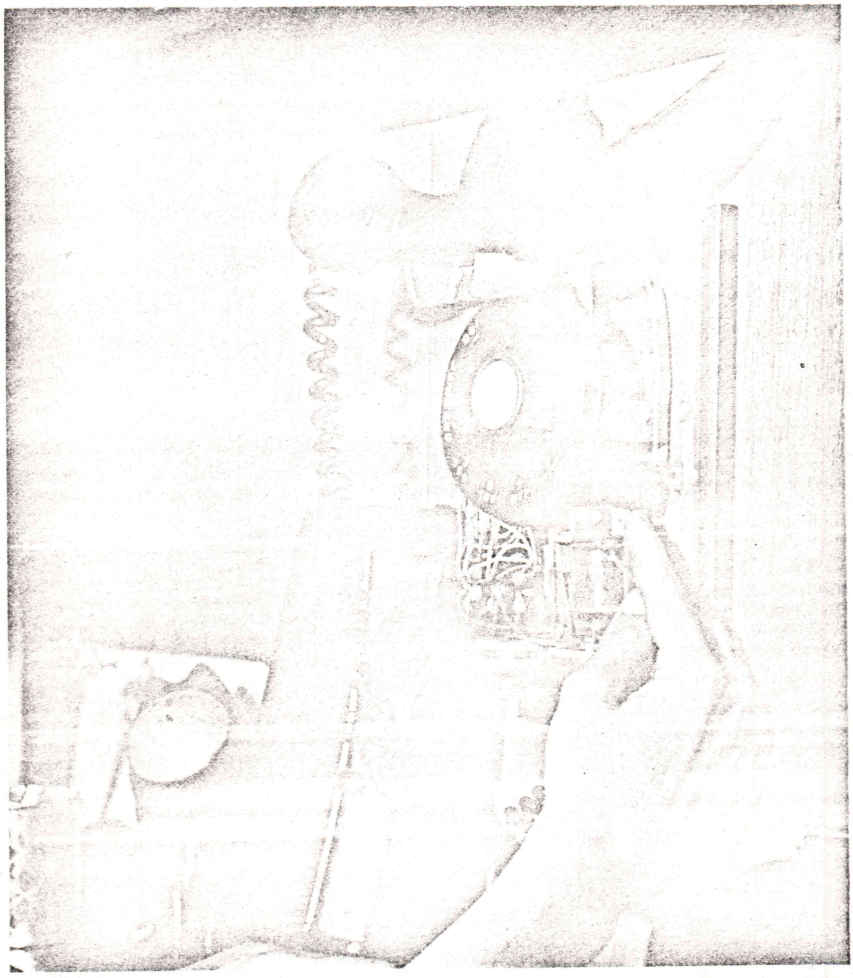


Figure 5-19. Example of capacitive-coupling to telephone line.

Capacitive-coupling is accomplished by wrapping one lead of an additional extension pair around each of the conductors of the pair under observation and feeding this extension pair to a high-gain amplifier. Again, this technique is useful in open country where such open-wire or twisted-pair conductors are sometimes used. Additionally, in some older hotel and office buildings will be found inside station wiring of the twisted-pair type. Here, also, the capacitive-coupling technique may be employed. Figure 5-19 illustrates capacitive-coupling to a pair. In the event that the circuit is a single-wire, earth-return type, one lead may be wrapped closely around the single conductor while the other lead is well-grounded. This circuit is sometimes employed in foreign areas, in the open country and in some field military installations.

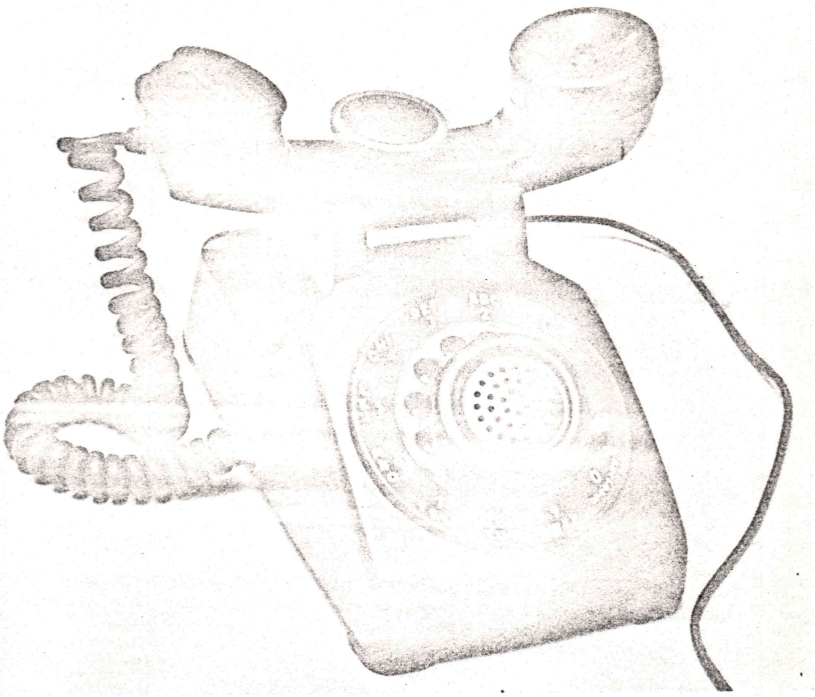
Line Tap Radio Transmitters

Radio transmitters designed for telephone line input may be connected at any point in the circuit by direct connection, by inductance or by capacitive-coupling just as are the direct tap circuits presented herein. Most commonly, however, they will be found connected somewhere between the subscriber's telephone and within a few blocks therefrom. They may be of the series-connection type or of the parallel-connection variety. Often, the series-connected "bugs" are powered by a small current "sampled" from the telephone line and use no external battery. They also may feed their r-f signal, through capacitance, back into the telephone line, although certain models utilize an external antenna.



Line-powered telephone line transmitter mounted inside a wall-mount 500-series telephone set. Note the antenna standing upright, resulting in maximum radiation effect.

Parallel-connected bugs are most commonly powered by an external battery and are provided with an external antenna. Any of these units may be hidden in the case of the telephone instrument itself or in, or around, any of the terminal boxes. It is also feasible to install them anywhere along the line in locations that are physically inconvenient to search, such as in a narrow crawl space under a house containing no basement. Another



A 500-series telephone set containing a line-powered (or in-line) telephone line transmitter disguised as a microphone. The original carbon telephone transmitter unit is shown balanced on the handset, with the cap placed on the dial face.

favored location, due to the advantageous siting of the antenna, is in the attic of a house where either the inside station wiring passes through the attic or where a hidden extension may be brought up from the nearest suitable point it does appear. Line-powered units do not have to be serviced, of course, and may be "buried" in locations that would be inconvenient to service. Battery-powered units, on the other hand, must be reasonably available for someone to renew the power supply periodically. Examples of each type are shown at the end of this chapter. Several of the line-powered devices have been built into components which are disguised to appear as normal parts of the telephone circuit. Two examples are the telephone transmitter

unit bug, which resembles the WECo F1 and T1 microphones, and the bug disguised as a WECo 425E network, complete with appropriate markings. Also found are bugs disguised as WECo U1 receiver units. To install the microphone type one merely unscrews the microphone cap of a telephone handset, removes the microphone and replaces it with the transmitter disguised as a microphone. The receiver unit is installed almost as easily, but one must remove the earpiece cap and detach two existing spade lugs and reattach them to the two screws on the underside of the transmitter disguised as the U1 receiver unit. The unit then is dropped in place and the earpiece cap replaced. These units may be installed quickly, used for a limited period and removed easily, leaving no trace of their employment. In other instances such units might be concealed inside protector boxes or in the terminal boxes themselves. (See also Chapter 6 on countermeasures for supplementary information.)

INVESTIGATIVE TRANSMITTERS

It may be observed that the adaptation of transmitters to investigative use involves either one of two basic types of transmitters. One type is the one to three-transistor noncrystal-controlled circuit, while the other involves the use of a six- to twelve-transistor, crystal-controlled frequency circuit.

The small, noncrystal-controlled transmitter consists typically of an oscillator whose frequency is controlled by a slug-tuned coil in the tank circuit, a stage or two of audio amplification modulating the oscillator's output and, in some cases, a tuned-circuit r-f power amplifier. The advantages offered by these circuits include extremely small size, low cost, low rate of power consumption and short operating range which would limit interference with other authorized services. The disadvantages of this transmitter include short range, which necessitates the placement of the receiver nearby, and relatively unstable frequency control which, at times, requires re-tuning of the receiver. With the advent of transistorized transmitters and receivers, the problem of frequency drift has been greatly minimized. Another significant disadvantage is that they are usually quite sensitive to changes in the effect of

body capacitance with relation to the antenna. As the antenna moves back and forth, in close conjunction to the body of an operator where the transmitter is concealed within the clothing, the operating frequency has a tendency to shift dramatically. These transmitters are best used in stationary locations where body-capacitance problems are minimized.

With regard to the crystal-controlled transmitters, almost all of them sold on the investigative market are merely adaptations of the transmitter section removed from ordinary "handie-talkie" two-way radio transceivers. Most transceiver transmitters consist of a crystal-controlled oscillator, a stage or two of audio modulation, several frequency multiplication stages, an r-f driver stage and an r-f power amplifier stage. Most of these transmitters are designed to transmit a watt or two of r-f power. When adapted to investigative use the final r-f power amplifier is removed and the reduced-level r-f signal is taken directly from the r-f driver stage and coupled, with suitable tank circuit, to the antenna. The output of such an altered transmitter will be found to be from 200 to 300mW.

Some concerns offer also an r-f "power booster" which usually consists of the missing final r-f amplifier mounted in a separate case. With this augmentation, the r-f output of the transmitter is boosted back to a watt or so at great expense in battery current consumption. The effective range of the 250 mW transmitters, at best, in suburban areas varies from about four to six square blocks, while in heavy steel and concrete urban areas the range may be easily less than one block. With the addition of the heavy current-drain booster amplifier the effective range may be increased somewhat. Up to eight to twelve miles has been achieved in desert locations. Only a few hours of use, however, may be expected of the batteries in the r-f power amplifier; thus frequent replacement opportunities must be provided if sustained use is anticipated. The advantages of this type of unit are extended range, where required, and frequency stability of the transmitted signal. In addition, these units are less affected by body-capacitance than the noncrystal-controlled transmitters. Disadvantages include extremely high cost, comparatively large

size, greatly increased battery current consumption and the capability of causing interference with other authorized users of the surveillance channel. The likelihood of unauthorized reception of the surveillance signal is also increased as a function of the use of the more powerful transmitter, as is the ease with which the signal may be detected by countermeasures personnel.

It becomes necessary for the investigator to decide what type of equipment is best suited to the need at hand, considering all of the limitations of the equipment he has available.

These transmitters ordinarily may be found operating in the 30 to 50 MHz, the 72 to 76 MHz, the 86 to 110 MHz, the 150 to 175 MHz and the 220 to 600 MHz bands, although they are not limited to any of these segments of the r-f spectrum. Two recent versions of the F-M transmitter concealed in a case disguised as an olive operate in the 86-110 MHz region and at 3,000 MHz.

The antenna tank circuit of each of these transmitters, in order to function at a maximum level of effectiveness, must be "peak" tuned for maximum signal strength. This tuning, performed by varying the capacitance in the antenna tank with a plastic wand, may be indicated on an adjacent field strength meter and should be done with the transmitter in the chosen location. Antenna length, for optimal results, should equal a quarter, or five-eighths of the operating wavelength. If it is necessary to operate using a shorter antenna, a corresponding reduction in signal strength may be expected. The author has experimented with a three-transistor transmitter circuit, operating at 90 MHz using a 36-inch antenna and achieved a useful range of three linear blocks in a suburban area. With a 12-inch antenna the range was reduced to 200 feet, and with only a one-inch antenna a range of 30 to 50 feet was obtained.

As with audio amplifiers, the input to the transmitter may be adapted to telephone line input rather than to the normal microphone. In this instance a d-c blocking, impedance-matching, network is substituted therefor and the telephone conversation is broadcast on an r-f carrier. Circuits are available that are battery-powered or that draw their operating current from the telephone line itself. Some circuits are designed so that they

radiate a signal only when the telephone line is in use. In this way, they are more difficult to detect through r-f field detection methods but, on the other hand, they may be easily located by line resistance measurements.

Investigative Receivers

The most effective receivers utilized for investigative purposes are double or triple conversion superheterodyne models. They may be F-M or A-M and for effective results should have a sensitivity of less than 1μv. The image rejection figure should be high, and the unit should have capability of 110 VAC, 12-volt automobile battery or internal battery power supply. Additional desirable features include automatic gain control (AGC), automatic frequency control (AFC), along with a defeat control for each of these features should their use be contraindicated, and separate headphone and recorder jacks. Signal-strength and deviation meters are also useful. The receiver antenna employed is most often a coil-loaded vertical whip, although a tuned dipole antenna, correctly oriented, is generally much more effective. Small directional dipoles may be used in order to pinpoint the location of a hidden transmitter, although those that are manageable in size are often less responsive than a full-size half-wave dipole in effective signal strength.

The fixed-frequency, crystal-controlled receiver sold with the extremely expensive investigative kits consists (similarly to its transmitter) merely of the receiver section of a two-way handie-talkie, mounted in a separate case with self-contained battery power supply. Such units may be easily constructed by purchasing from one of the large suppliers (such as Motorola, General Electric or RCA) separate receiver and transmitter strips and enclosing them in individual boxes. This may be done at a saving of up to $500 over the cost of the units if purchased through investigative supply sources.

Late model transistorized, variable-frequency, F-M receivers with better than ½μv sensitivity have recently been introduced on the market. Most of these have at least one optional crystal-control feature. Using the same basic circuit, other models with up to eight crystal-control positions are available. Prices for the

variable-frequency model are less than $70, while a six-position crystal-control model retails at less than $100. Another model, with automatic scanning and selection, of eight crystal-control channels is available for less than $140. These prices may be contrasted with the $500-tag carried by most investigative equipment suppliers' receivers. A Motorola crystal-control F-M receiver strip, on the other hand, might be priced at $140. Transmitter strips, from Motorola or Radio Specialties Mfg. Co., for example, might be priced at $90, while the police equipment supplier asks $500 or so for the same item in a different package.

In the use of a variable-frequency receiver, an advantage exists over fixed-frequency models. The variable model may be instantly tuned to transmitters of different frequencies or may be retuned slightly when the transmitter alters in its output frequency as the result, for example, of detuning of the transmitting antenna.

Line-Carrier Transmitters and Receivers

By coupling the r-f output tank circuit of a transmitter to a 110 VAC power line, through suitable coupling capacitors, the r-f signal may be radiated through the a-c power line, rather than through the air, and may be received by a suitable similarly-coupled receiver anywhere on the same winding side of the a-c power supply transformer.

Through the use of a high-frequency, crystal-controlled oscillator at the receiver the hidden transmitter may be turned off and on at will through the use of a tuned r-f relay wired into the power supply of the transmitter. Thus the unit may be left idle and (ordinarily undetectable) actuated by the operator of the monitoring receiver only when it is desired to receive the signal from the hidden transmitter. These devices, when in use, are easy to discover since they place a continuous r-f carrier on the power line. The tube models are difficult to conceal, due to their size, and generate considerable heat when in use, presenting somewhat of a fire hazard when concealed within walls. Methods of disclosure of this type of surveillance device are covered in the chapter on countermeasures, which follows.

"THIRD WIRE" OR "HOT MIKE" TECHNIQUE

Below are shown the methods of energizing telephone sets for use as in-place microphones and monitoring sounds which occur adjacent to their location.

300 Series Telephones

Private Line

Turn the telephone set upside down and loosen the two inset lockscrews on the base of the instrument. Separate the base and top of the instrument, placing the parts adjacent to each other on the working area. Remove the old set mounting cord observing carefully the terminals from which the colored conductors were removed. Attach the new four-conductor set mounting cord (WECo D4AN 5'6") to the telephone base, being careful to connect the red and the green conductors to the same terminals to which the original set mounting cord's red and green conductors were attached (red to "L1" terminal of the induction coil and green to "L2" of the induction coil). Attach the yellow conductor to the "R" terminal of the induction coil. Next, run the black conductor of the new set mounting cord through existing retaining clips and attach its lug to the dial strip terminal which bears the two black conductors already installed (the second terminal from the left, looking into the underneath portion of the top of the telephone instrument case), thus "jumping" the switch on the microphone leads. Be careful to replace the remaining wires as they were found inside the instrument, and be sure that none of the terminals adjusted are shorted to other terminals, since the telephone company trouble desk may be signaled and subsequent discovery of the "bug" follow. Replace the base of the telephone instrument by tightening the inset lockscrews.

Next, remove the connector block cover (the cover of the 2 inch by 2 inch baseboard-mounted connector block) and remove the old set mounting cord conductors from the terminals to which they are attached. Note carefully the location of each lug of the various colored conductors. Secure the conductor lugs of the various colored conductors. Secure the conductor lugs of the

new set mounting cord to the connector block in the same fashion as the old conductor lugs were fastened. Connect the red conductor lug to the screw binding post which was occupied by the red conductor lug of the old set mounting cord; then connect the green conductor lug to the screw binding post which was connected to the green conductor lug of the discarded set mounting cord.

Drill a ⅛-inch or ¼-inch hole through the baseboard, directly to the rear of the connector block, in such a fashion as to be concealed when the cover is replaced. Pass or fish a light twisted pair through the hole and into the basement, closet, et cetera or wherever it is desired to lay the microphone cable. When sufficient wire has been passed, cut the pair at the connector block, leaving sufficient length to make soldered joints at the block. Strip the insulation from one end of the pair and solder the bared end to the lug of the yellow conductor; solder the other bared end to the lug of the black conductor of the set mounting cord. Tape both joints with plastic electrical tape and take up the slack by pushing the twisted pair down through the new outlet. Conceal the wires in the connector block and replace the connector block cover. This completes the installation within the room "plant."

Lay the twisted pair to wherever the recording instrument or monitoring amplifier will be installed, and feed one conductor to the low-impedance side of a 200 Ω to Hi or Lo-Z recorder-matching, audio input transformer. Connect the other conductor to one side of a low-voltage (1½ volt to 6 volt) dry battery. The other pole of the battery is then connected to the other side of the low-impedance portion of the microphone transformer. The high-impedance side of the transformer is connected to the recorder or amplifier in the normal manner for the proper impedance input.

The microphone of the telephone in the "bugged" room is now a "hot mike" and functions as a sound pickup twenty-four hours per day using one of the most sensitive microphones made. No interference is caused with the normal telephone service. This technique is useful where it is impossible to run microphone cable

into a room which already contains a telephone installation. It may be easily detected, however, by removing the plastic transmitter cap of the telephone handset, depressing the hook-switch and making a voltage measurement of the microphone terminals with a voltmeter. With the hook-switch depressed no voltage should appear across the terminals if the telephone is not connected as a "hot mike" or "third-wired."

Party Lines

The same steps are followed, except that a five-conductor cord, WECo D5AA 5'6", is used. The red, green and yellow terminal connections at the telephone base and at the connector block are made with the same conductors of the new cord in the exact same manner as were the identical conductors of the old cord. The two additional conductors, the black and the blue leads, are connected as follows: the black conductor is attached to the dial strip bearing the two black conductors (the second terminal from the left as you examine the interior of the upside-down set), while the blue conductor is attached to the "R" terminal of the induction coil. The instrument is reassembled, and the spare pair is run through the rear of the connector block in the normal manner. This completes the "third-wire" connection for a party line telephone set.

500 Series Telephones

Turn the telephone set upside down and loosen the lock screws, located at each end of the mounting plate, with a screwdriver. Remove the top of the case and set it aside. Place the telephone base on a surface and observe the potted network located at the right center of the base. Loosen the lug-mounting screws of the red, the green and the yellow conductors in the set-mounting cord. Note that the red conductor was fastened to terminal "L1" and the green conductor to terminal "L2," with the yellow conductor connected to the terminal marked "GND." Remove these conductors, unhooking the set-mounting cord from the base and replace with a new WECo D5AA 5'6" set-mounting cord. Connect the new set-mounting cord in the same manner as the one replaced, hooking the strain relief into the base and

connecting the red, the green and the yellow conductors to the proper terminals. Observe that two extra conductors (black and blue) are included in the new set-mounting cord. These spare conductors will carry the microphone current in the altered circuit. Connect the lug of the black conductor to the "B" terminal of the network and the lug of the blue conductor to the network's "R" terminal. At this point, the work within the instrument is completed. Replace the plastic cover on the base, turn the unit upside down and tighten the two lock screws. Remove the cover of the baseboard-mounted connector block by loosening

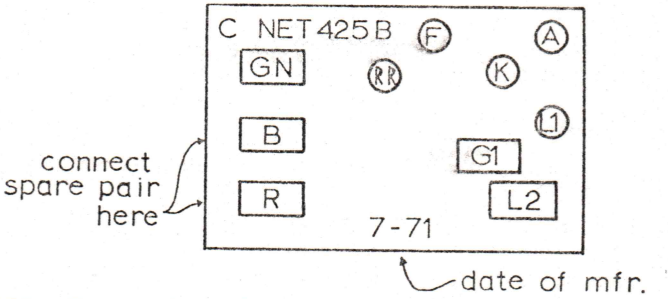


Figure 5-20. Typical "hot-mike" connections to a WECo 425B network.

the center lock screw with a screw-driver. Remove the lugs of the old set-mounting cord, noting carefully the locations of the colored conductors. Replace the lugs of the new set-mounting cord so that the red, the green and the yellow conductor lugs are connected to the same terminals to which the corresponding lugs of the old set-mounting cord were mounted. Next, drill a ¼-inch or ⅜-inch hole through the baseboard directly to the rear of the connector block so that the hole will be hidden when the connector block cover is re-installed. Fish a twisted pair of wires through this hole and run them to the location of the plant. Finally, solder the black conductor lug to one wire of the pair and the blue conductor lug to the other wire. Tape both joints carefully with electrical tape and arrange the wires so that they fit easily inside the connector block cover. Lastly, replace the connector block cover and the inside room-work is complete.

The twisted pair across the telephone microphone are always "hot" and should be connected across the primary of a 200Ω to Hi or Lo-Z microphone matching transformer, with a 1½ volt to 4½ volt battery connected in series with one leg of the primary winding to energize the carbon microphone. The Hi-Z side of the transformer is connected to the proper impedance input of a recorder or amplifier through shielded cable. The installation is now completed, and all sounds produced in the vicinity of the "hot" microphone may be monitored and recorded continuously. The same condition may also be created through the employment of a neon lamp, an SCR, or with a Zener diode *without* adding the extra conductor. Figures 5-21 through 5-32 show numerous surveillance devices and accessories described in the text.

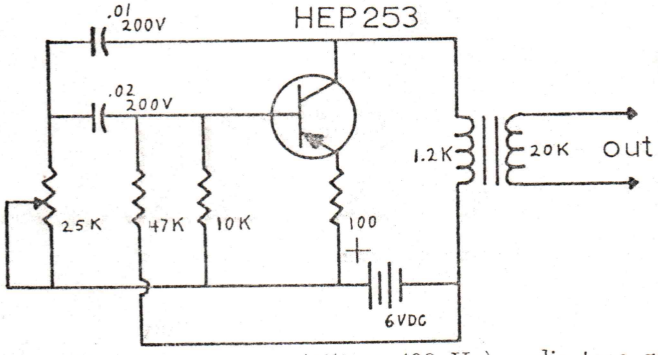


Figure 5-21. Variable-frequency (150 to 400 Hz) audio tone generator.

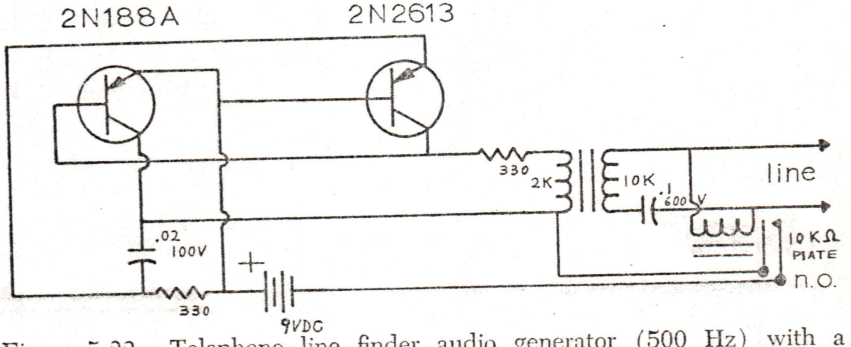


Figure 5-22. Telephone line finder audio generator (500 Hz) with a circuit which automatically disengages when the line is in use.

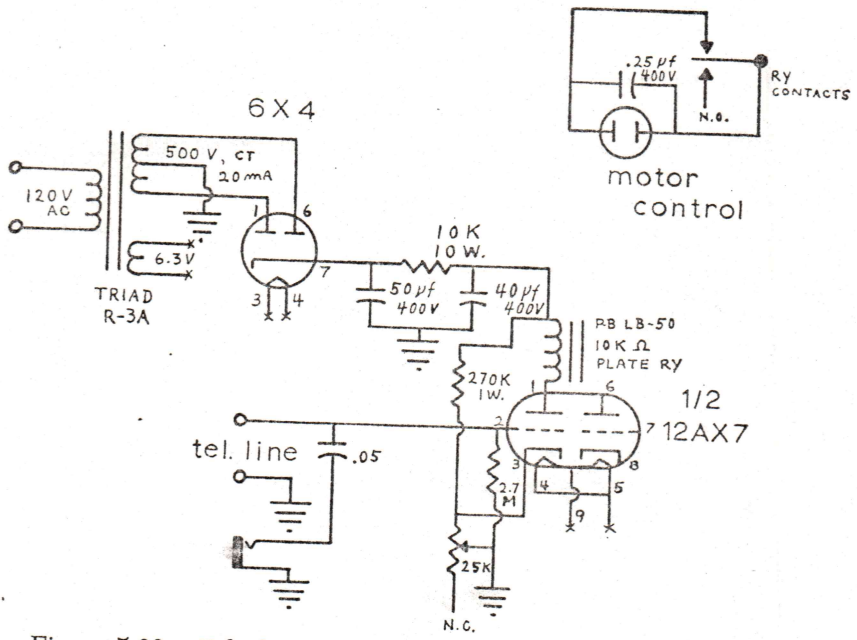


Figure 5-23. Telephone line activated relay (tube) for separate use.

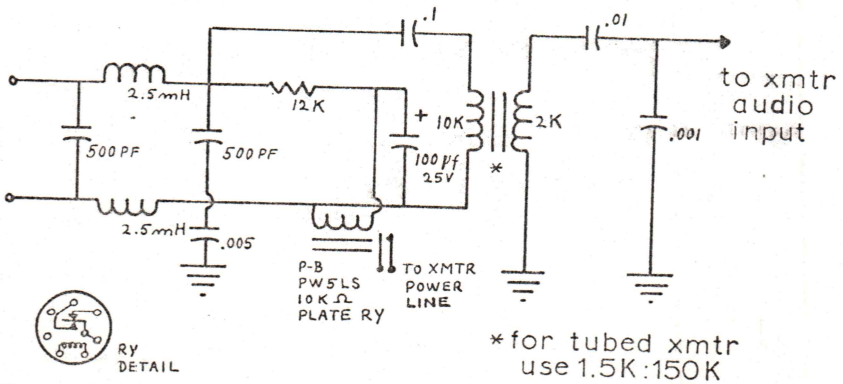


Figure 5-24. Telephone line activated relay with input-matching network, for control of a radio transmitter.

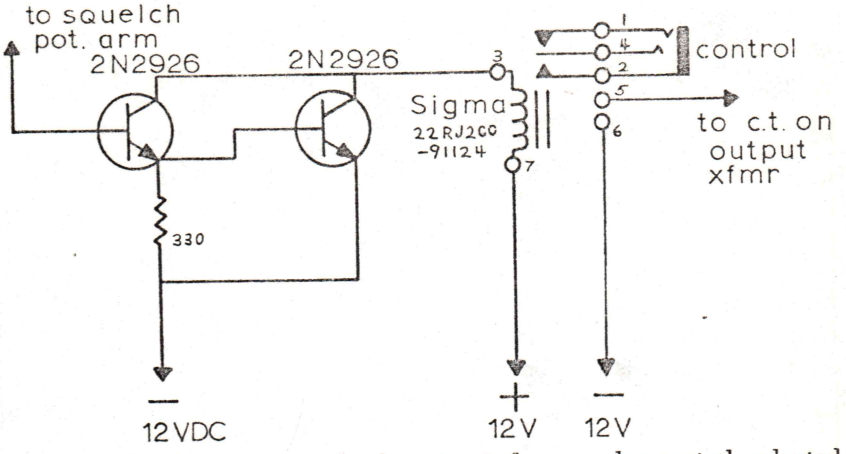


Figure 5-25. Carrier-operated relay circuit for recorder control, adapted to existing surveillance receiver.

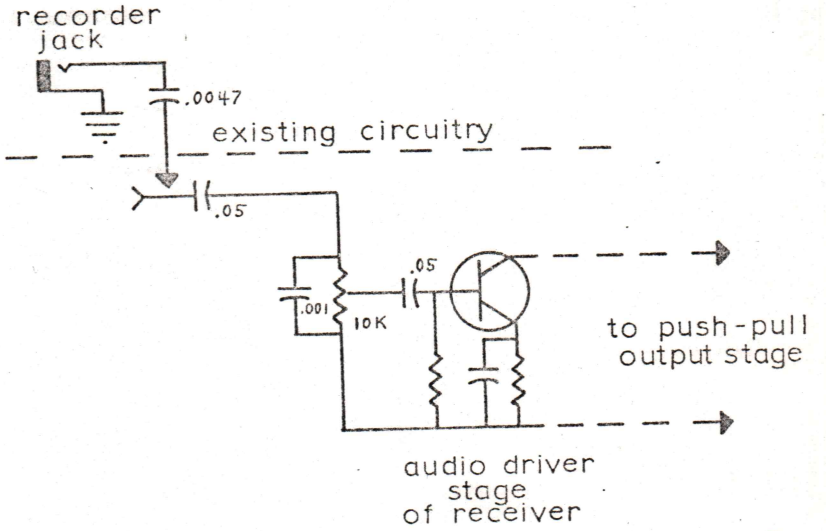


Figure 5-26. Recorder output circuit adapted to existing surveillance receiver.

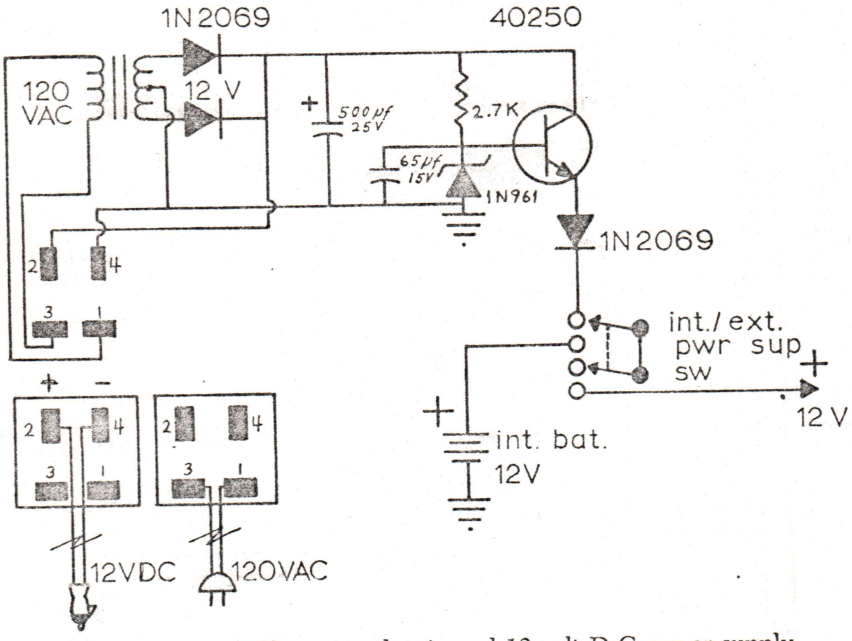
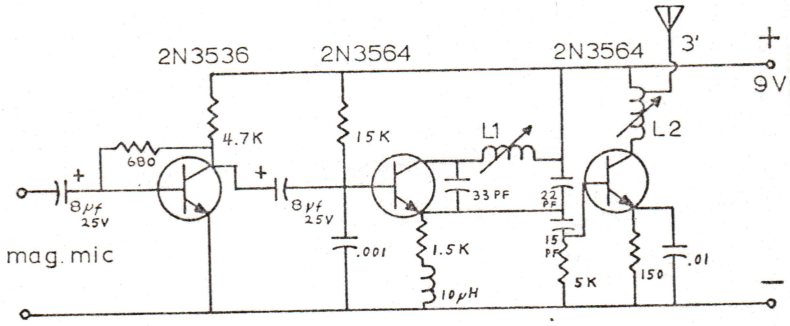


Figure 5-27. Self-contained universal 12-volt D-C power supply.



L1 -13 t No. 26 enam, cw on 7/32" form brass slug
L2-13 t No. 26 enam, cw on same form tapped 3t from + end for ant.

40-50 MHz
C3-60 pf
C4-40 pf
L1 -25 t No. 26, tapped 5 t from + end ant. 6'

Figure 5-28. F-M transmitter, 85-110 MHz or 40-50 MHz.

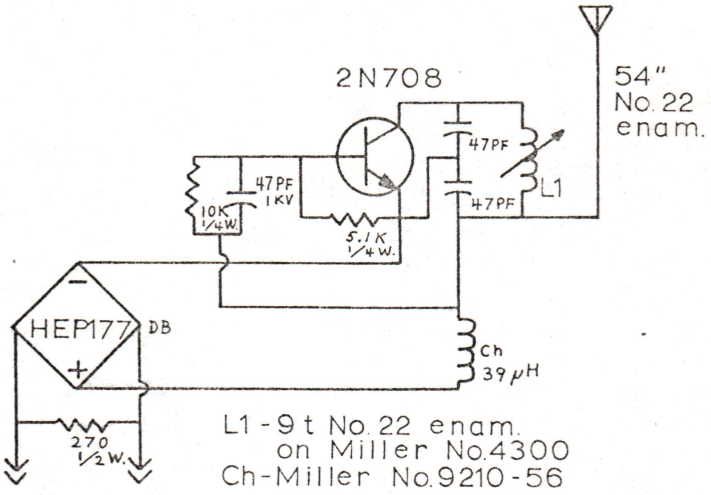


Figure 5-29. F-M telephone line transmitter, 45 MHz, line-powered.

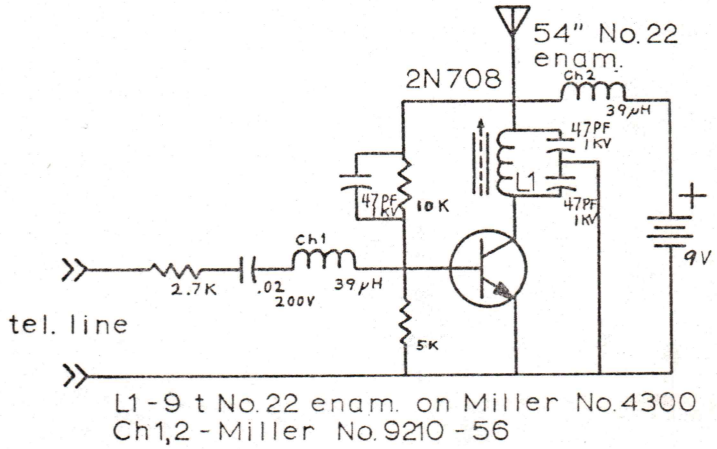
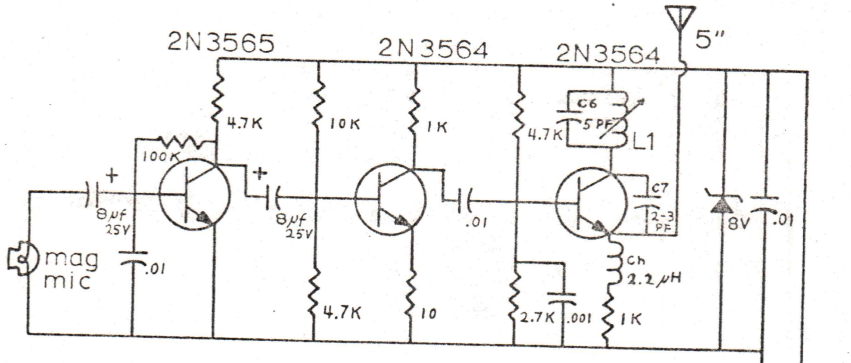


Figure 5-30. F-M telephone line transmitter, 45 MHz, battery-powered.

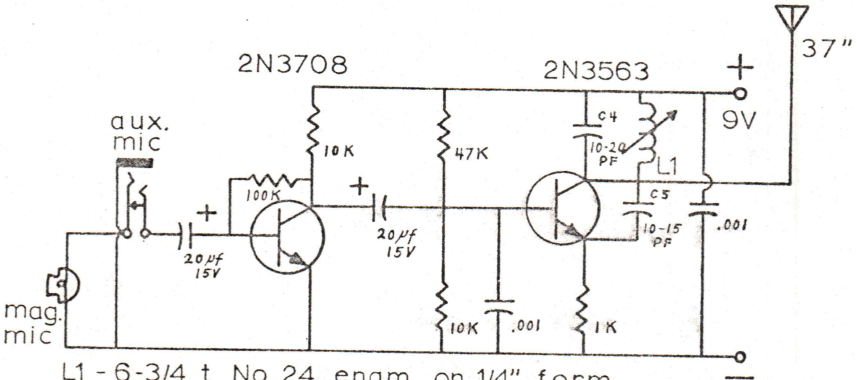


L1 - 4 t No. 20 enam, sp to 1/4" on 7/32" form, brass slug
Ch - Miller No. 9310-20

40 - 50 MHz

C6 - 8 pf
C7 - 4-5 pf
L1 - 7 t No. 20 enam same sp & form
ant - 9"

Figure 5-31. F-M telephone line transmitter, 85-110 MHz or 40 to 50 MHz, line-powered, disguised module built inside case resembling a telephone transmitter unit; drain 10 mA.



L1 - 6-3/4 t No. 24 enam. on 1/4" form with ferrite slug

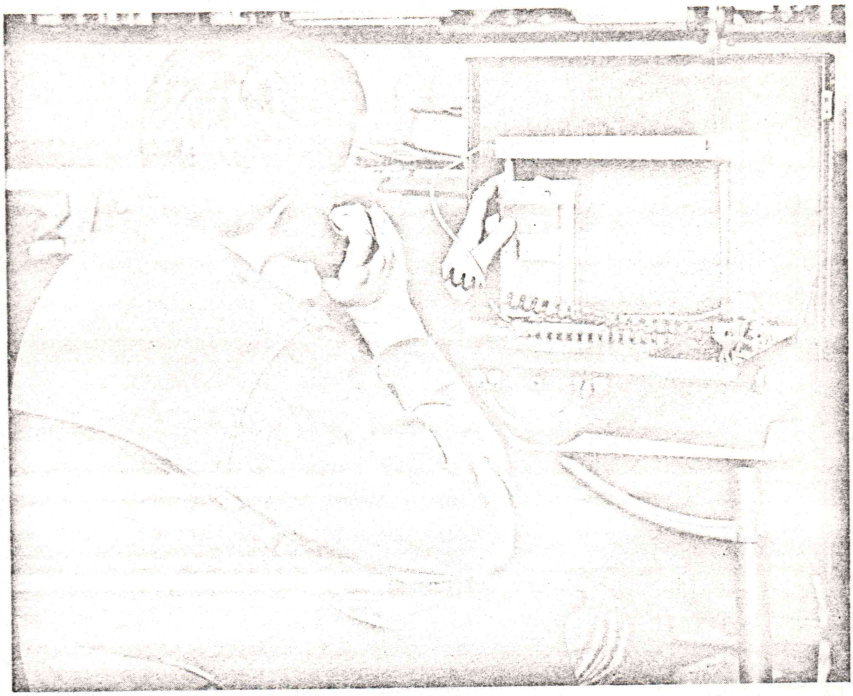
30 - 40 MHz

L1 - 7-3/4 to 8 t No. 24 en.
C4 - 15 to 20 pf
ant - 38"

90 - 100 MHz

L1 - 6-1/2 t No. 26 en.
C4 - 5.6 pf
C5 - 3.3 pf
ant - 20"

Figure 5-32. F-M surveillance transmitter, 30 to 40 MHz, 40-50 MHz, or 90 to 100 MHz.



A magnetic tape recording being made of mobile radiotelephone traffic, through the use of a portable 11-channel radiotelephone concealed in a dispatch case and a miniature cassette recorder. It may serve as a reminder of the lack of security inherent in such a system.

Chapter 6

ELECTRONIC SURVEILLANCE COUNTERMEASURES

COUNTERMEASURES IS A term used to describe those methods used by security personnel to defend against the use of electronic audio surveillance devices. It is more than just a technical searching and checking process; it is also, ideally, a state of mind—a manner of regarding situations from a technologically defensive posture.

Technical measures include the random, unannounced, periodic examination of protected premises in conjunction with a stringent personnel security policy and an effective system of access control. In protected areas, only those persons bearing proper security clearances and a demonstrated need-to-know should be granted access. Facility communications centers should always be classified with as high a degree of security as any of the offices served by the communications center. Access to these areas by repairmen of any type, under any conditions, should be granted accompanied by a *countermeasures-trained security officer.* This security officer must remain with the repairman constantly, observing all of his activities while he is in the sensitive area. Before admitting such repairmen, or any other personnel, their credentials should be checked by experienced security officers and their *identity* and *authorization* for the visit should be verified with their office of record. It is not enough to merely telephone the number supplied by the visitor or that which is printed on his calling card. Obviously, these can be produced at will by anyone, as can identity cards and documents.

This chapter is logically divided into sections dealing with the

instruments and tools used in electronic surveillance countermeasures, defense against wired and other microphones, defense against telephone taps, defense against surveillance transmitters, the search of automobiles, the construction of secure rooms and some observations on personnel security.

INSTRUMENTS AND TOOLS

Required by the countermeasures technician is a complete set of small hand tools with which he may dissassemble the various equipments, objects and structures he is required to search or examine. Included here would be an assortment of slot-screwdrivers, phillips-head screwdrivers, adjustable wrenches, diagonal cutting, needle-nose and utility pliers, an electrician's knife, a pair of good electrician's scissors, a hand mirror, a small mirror mounted on an extension shaft, a dental mirror, a powerful Alnico magnet mounted on an extension shaft such as that used by machinists, a roll of plastic electrical tape for repairing wires he may find it necessary to cut, several cans of various commercial solvents such as acetone, methyl ethyl ketone, carbon tetrachloride, naphtha and alcohol (these are used for removing finishes from freshly-finished work in suspicious locations), and several sets of six-foot jumper cables equipped with needle-piercing alligator clips at both ends.

Instruments available must include a good volt-ohm-milliammeter (VOM), the equal of Hewlett-Packard, Motorola, Simpson, Triplett or Weston, along with a set of alligator-clip and wire-piercing probes. A general purpose, battery-operated transistorized audio amplifier with both high- and low-impedance inputs and a headphone output is of very great importance. This amplifier should be equipped with a high-impedance, shielded, input cable and a low-impedance, unshielded, input cable.

In addition, a transistorized metal locator, a transistorized audio-frequency oscillator, an a-c voltmeter, also calibrated in decibels, and a white-noise audio-frequency generator with telephone line input are required. A radio-frequency noise generator, and a supersonic frequency generator each may be used to

advantage along with radio-frequency detectors, telephone and/or radio speech inverters (scramblers) and an all-wave surveillance radio receiver. Included, also, should be a board-band sweep generator of high output. Finally, a high-voltage-low-current power supply for checking telephone sets and a high-voltage-medium-current power supply for destroying unauthorized line devices will prove of utility.

MICROPHONES

One of the first considerations in a room search for hidden microphones is the question of prior occupancy of the room or building. Who had prior access to the premises is a factor worthy of consideration. If the building had been occupied by, or had been given access to, inimical groups, it may be assumed that there is a good chance that listening devices have been planted therein. A typical technique is to leave several listening devices where they may be found by a reasonably thorough search, with the hope that the other, more skillfully concealed, devices will escape detection.

All cables and wires run into the building from the outside or found within the premises must be investigated. This check amounts to a general observation of what type of wiring the cables are purported to be, along with a physical trace of the circuit. The cables are then tested for the presence of voltage. If this is found, the type of voltage must be determined. The cable is then monitored, isolated by appropriate capacitances, to ascertain whether it is bearing an audio signal. Wires may be identified as lighting, power associated, signaling, telephone or control wires. Among these are included intercommunication set wires, PBX board wires, annunciator wires and thermostat or other control or sensing wires. In addition to voltage checks and audio monitoring, these lines should also be checked for the presence of radio-frequency energy.

Next, a complete physical search must be made of every inch of wall, floor and ceiling space to include ventilators, heating ducts, the insides of lighting, power and telephone receptacles

and all of the furniture. In certain cases, removal of the wall panels or plaster might be necessary. In the event that unidentified wires are found, it is a good practice to set up a moderately loud, distinctive, noise source in the room and to subsequently test all of the wires for the presence of that noise. If such noise were heard over the monitoring amplifier, the indication would be that there was a functioning microphone attached to those wires. Its hiding place may be revealed by then connecting an audio generator to the unknown wires and listening with the unaided ear for such a-f tones to issue forth from the hidden location of the microphone. In this case the microphone will function as a miniature loudspeaker and the a-f tone will be heard near the microphone's location. If it proves impractical to remove, it may be destroyed in place by the application of high-voltage a-c from the high-voltage line destruction device. Care must be exercised here that unsuspecting friendly personnel are not working on or near the circuit when the high voltage is applied *because it quite possibly might be lethal.*

The lines should also be checked for the presence of radio-frequency energy by a sensitive untuned r-f detector for both radiation and line-carrier r-f waves. (See Figure 6-1).

Any signs of recent construction, alteration or repair must be investigated. It must be borne in mind that entire closed-circuit TV systems have been installed in ceilings or in newly constructed false ceilings during *overnight periods.* A ceiling need only be "dropped" a few inches in order to install a TV camera, or it may be installed in existing ceiling light fixtures in the space just above the ceiling.

Through the use of a supersonic frequency generator, any microphones within its range may be caused to heterodyne and issue forth a loud audible squeal. The supersonic frequencies, alone, are not detectable by the unaided ear. Should an animal or a person wearing a hearing-aid enter the supersonic wave area they will suffer great auditory discomfort, to say the least! Figure 6-2 shows such a generator.

Needless to say, all adjacent rooms including rooms above and below the security area must also be checked. If maximum

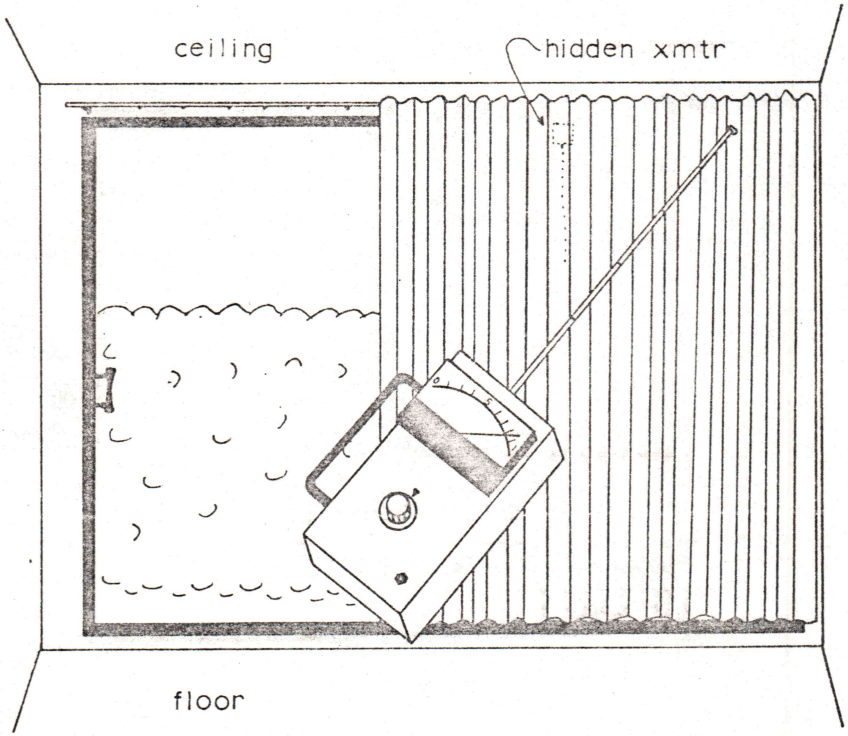


Figure 6-1. Use of R-F detector in room containing an energised transmitter; note meter deflection denoting presence of nearby R-F energy.

security is to be initiated, these other rooms must be placed under constant surveillance (meaning occupancy by security personnel, if necessary) during the period of the heightened security.

In emergency situations, such as unexpected conferences, the announced location of the conference may be changed by security personnel at the last minute with no previous announcement of the change. Further, it would be prudent to examine all briefcases and packages carried into the room.

In addition, white-noise audio generators may be set into operation or a white-noise generator fed into an audio amplifier with a continuous loop of resistance-loaded wire (surrounding the perimeter of the room) fed into the speaker terminals of the amplifier. The speaker, in this case, would be disconnected, as

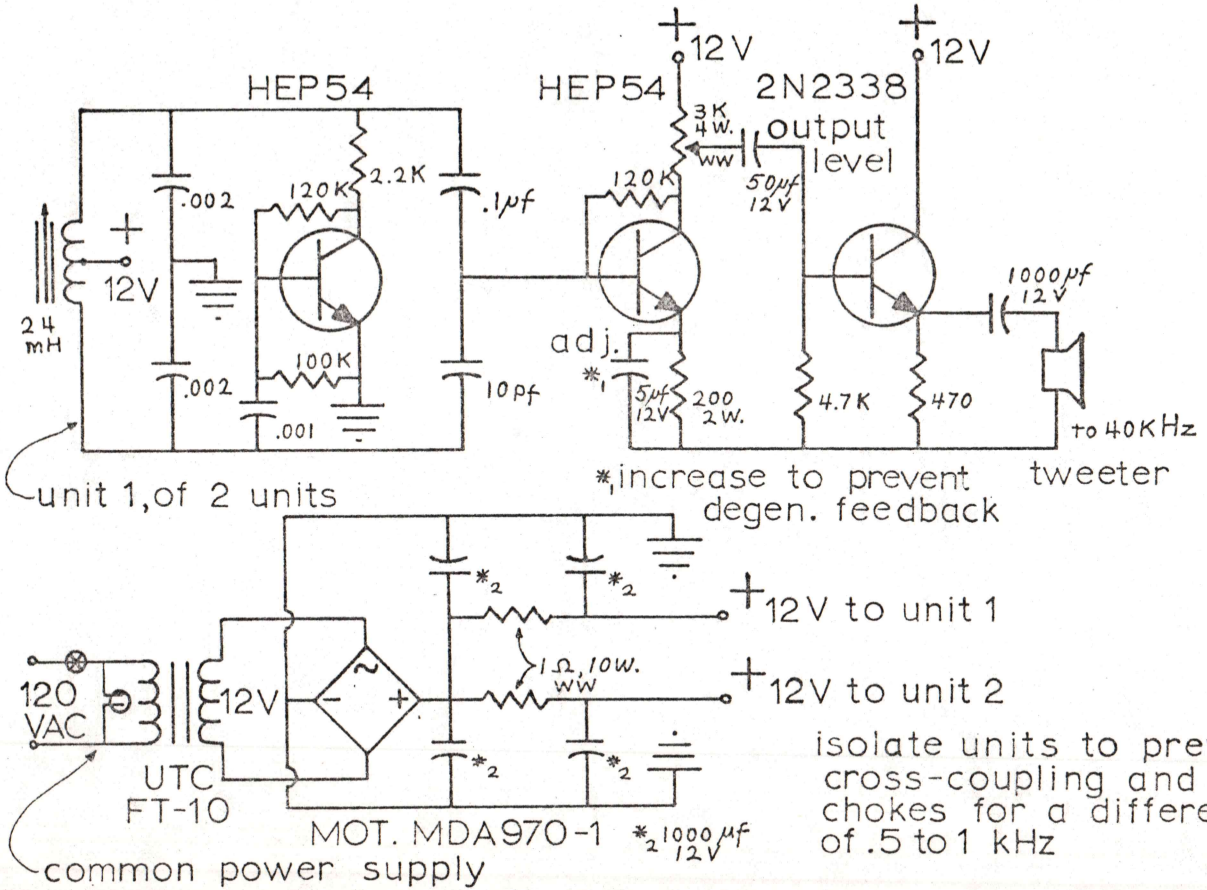


Figure 6-2. Supersonic frequency generator used to cause heterodyning in concealed microphones. Speakers are oriented toward ceiling, and separated by 10 to 15 feet or so.

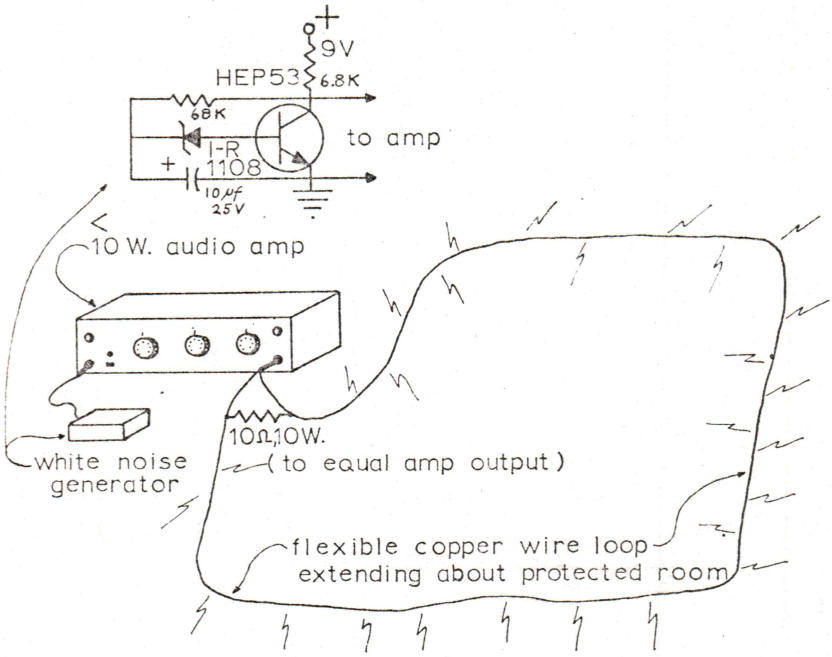


Figure 6-3. Protecting a room through the use of an electromagnetic noise radiating white noise generator; circuit also shown.

shown in Figure 6-3. The electromagnetic noise field created by this white-noise loaded loop would then be induced into any dynamic or magnetic microphone within its range. This would include those microphones used for wired amplifiers, magnetic recorders and radio transmitters.

Lacking such instrumentation, a radio receiver may be set to an interchannel position and the gain control advanced to the maximum. If an F-M receiver is available, it may be set to receive the white-noise hiss that may be observed between broadcast stations. Loud music from a radio, a phonograph or a television set may also be substituted. In a pinch, a confidential conversation may be conducted near a running bathroom shower head. The rushing sound of the water serves, in that case, as a form of white-noise.

Windows also present a problem, whether closed or opened. Directional microphones may be aimed at open windows and

sounds occurring within the room may be recorded satisfactorily from as far away as 250 yards, under beneficial ambient noise and weather conditions. Directional microphones may also be effective against *closed* windows when used at ranges shorter than 50 yards.

A continuous-wave laser beam may be reflected from the surface of a window, received and blended with a refraction of the original beam to produce a refringence which may be detected by a photoelectric cell. Any modulation of the laser beam, caused by vibration of the window pane, would be reflected back to the point of refringence and demodulated by an amplifier whose input is circuited with the photoelectric cell placed in the pattern or refringence. Should audio-frequency modulation be applied to the reflected beam, the pattern of refringence will vibrate slightly, producing slight changes in the light-dark areas of the pattern, in exact consonance with the audio-frequency impinging upon the surface of the window. It is possible for a low-powered, inexpensive ($200), continuous-wave helium-neon laser unit to thus function for a distance of *up to ten miles* from its target. Practical problems, however, arise over aiming accuracy and locating the exact area of the reflected signal. At closer ranges, of course, no such problem exists. The light beam thus generated is of such narrow dispersion that it may not be seen except when the observer looks into the direct part of the beam. Unfortunately at this point he also stands a good chance at being permanently blinded. A method of revealing the presence of such a beam is to cause a smoke source to pass in front of the window. If a laser beam is in use it will be plainly revealed as it bores through the smoke. This is caused by the reflection of the minute solid particles comprising the smoke.

It is, of course, possible to use a carbon dioxide infrared laser beam in the same manner, with the advantage of complete invisibility. A good defense against this technique is the use of double-pane thermal insulation glazing. The inside pane will vibrate, of course, but the air barrier in between the two panes prevents the outer pane from picking up the vibrations from the inner pane.

In addition, the use of grounded, conductive, glass panes along with metallic louvres or venetian blinds will defeat the use of beamed microwave transmissions.

TELEPHONE TAPS

In checking for the presence of telephone taps, the entire line must be physically searched, from the telephone set to the central office. This, of course, would have to include every appearance or bridging head. Telephone company assistance must here be obtained. For high-security lines, the installation of special pressure alarm gas-filled cable may be arranged, as can the employment of security foil-wrapped cable (the outer shielding of which is charged with wide-spectrum noise frequencies) associated with an alarm circuit for the detection of tampering.

On the protected premises, however, certain checks may be conducted on the lines. Each line may be disconnected at the terminal box or at the protector, and resistance measurements made of each separate conductor, and of the closed loops as shown in Figure 6-4. Resistance measurements differing from known conductor or loop lengths, or the existence of capacitance

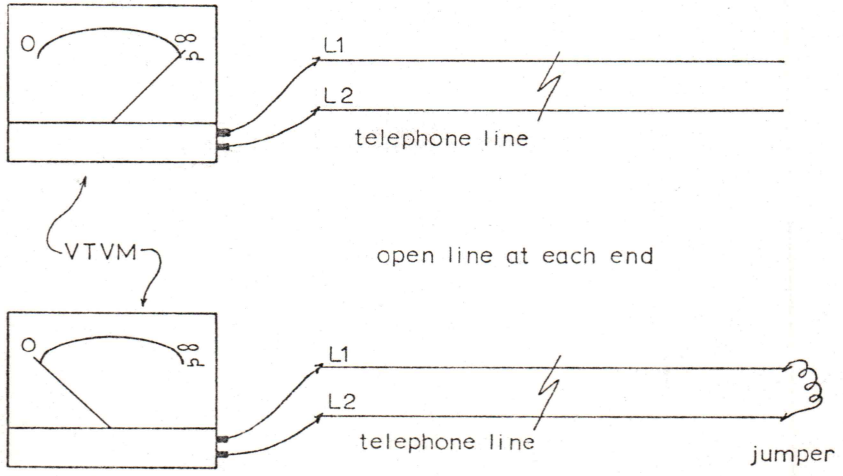


Figure 6-4. Appearance of normal, short loop, telephone line in a VTVM resistance measurement.

"kicks" on the ohmmeter are indicative of line bridging devices, shown in Figure 6-5 through Figure 6-7. It is for this reason that

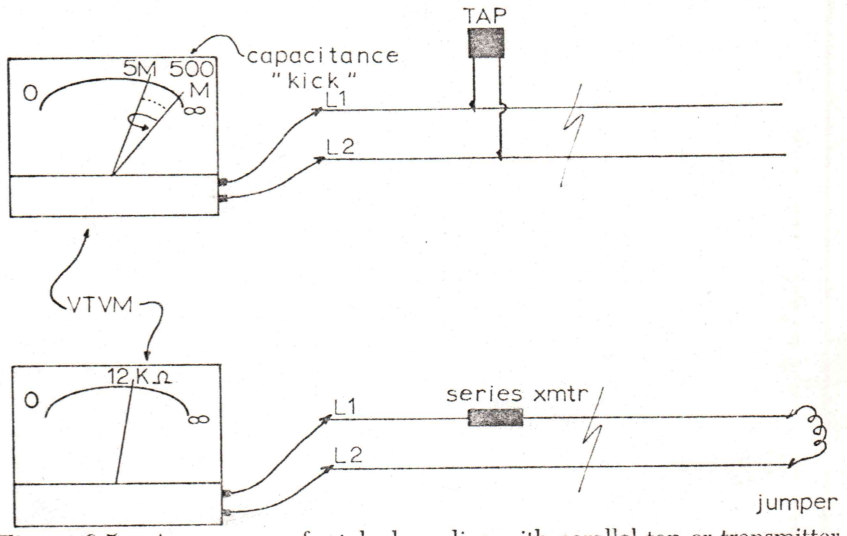


Figure 6-5. Appearance of a telephone line with parallel tap or transmitter and a series transmitter, in a VTVM resistance measurement.

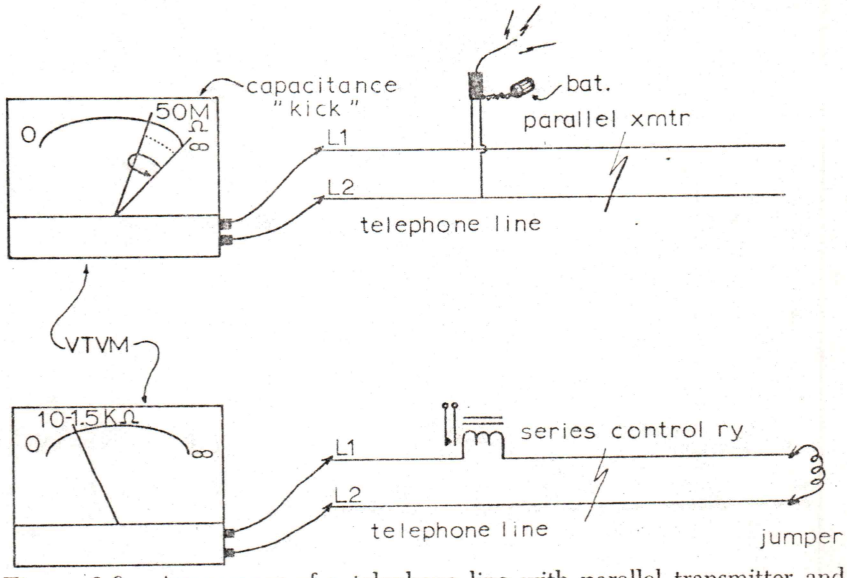


Figure 6-6. Appearance of a telephone line with parallel transmitter and a series drop-out relay used for recorder control in a VTVM resistance measurement.

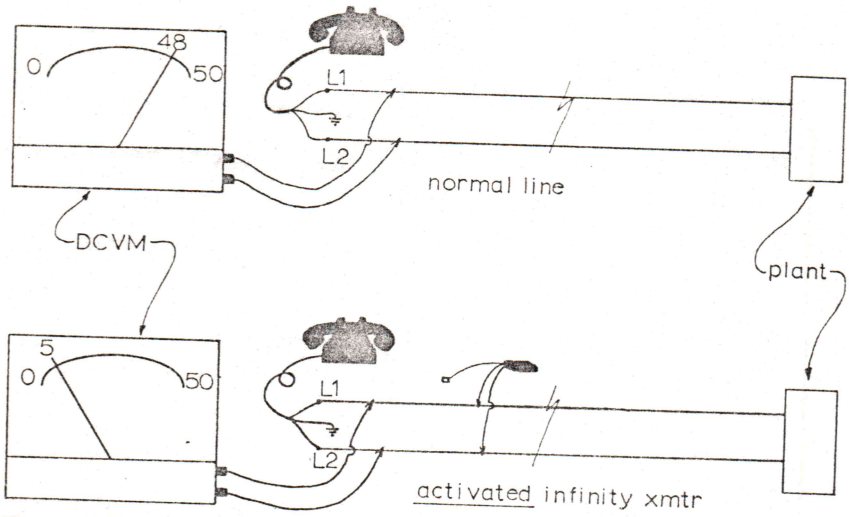
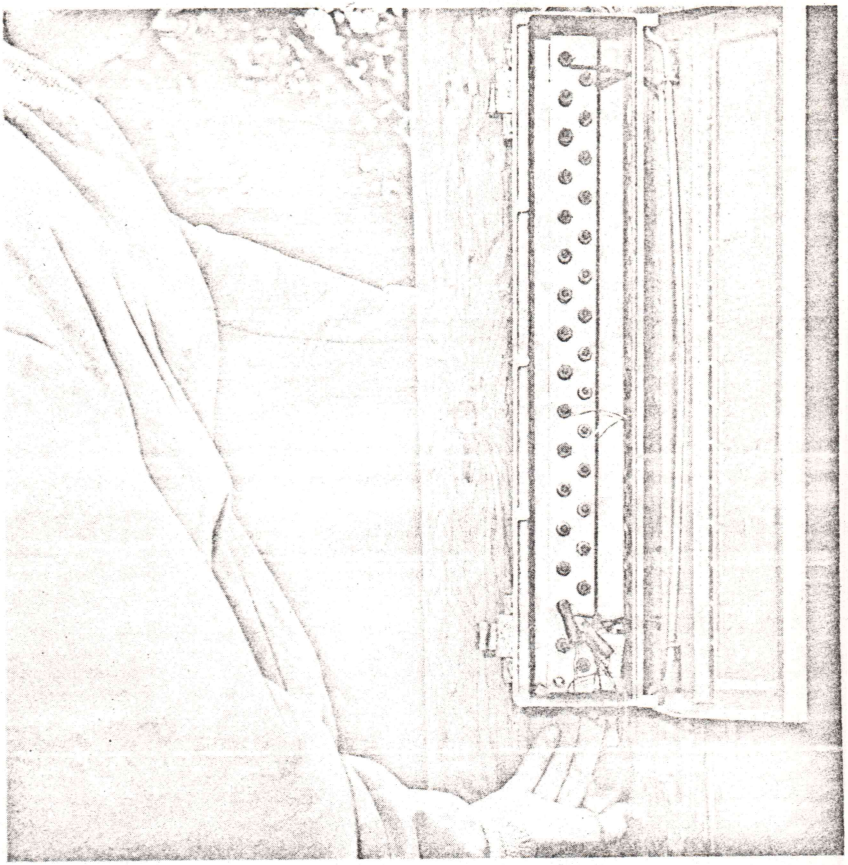


Figure 6-7. Appearance of a normal telephone line bridged with a voltmeter; the same line exhibiting signs that an *activated* infinity transmitter is in use.

short sections of the line are tested in turn. (See Appendix for loop resistance table.) The line may also be subjected to the scrutiny of both r-f radiation and carrier detectors. Suspected lengths of telephone line may be disconnected at *both ends* of the circuit and after appropriate warning to concerned personnel be exposed to the high-voltage line destruction device. Any unauthorized attachments will be literally caused to explode. Should a person be handling any of these devices at the time of the high-voltage surge, it is likely that he would be killed or suffer severe injury during the process.

Each telephone set, the switchboard and the cable vault must also be physically searched for unauthorized devices or attachments. Telephone sets may be concealed microphones, amplifiers and/or radio transmitters—all of which may be found during a physical search. Additional wires may have been added to bypass the hook-switch in what is called the "third-wire" or "hot-mike" technique. In addition, Zener diodes (avalanche diodes) may have been added or concealed within the subset to accomplish the bypassing *only* when activated by high voltage. This sort of



A 16-pair telephone terminal box containing a battery-operated (or parallel) telephone line transmitter. The battery is shown betweeen the terminal board and the case wall.

installation is detectable only by the test application of high voltage to the line by the technician.

Bypassed telephone microphones may be revealed by a voltage check of the microphone terminals when the telephone is in the "hung-up" position. The presence of any voltage indicates a bypass. (See Figure 6-8). Another technique used to reveal a bypassed microphone or receiver is to couple a small loudspeaker to both the transmitter and the receiver of a telephone handset at the same time and to feed a loud audio signal

An in-line (or series) telephone line transmitter in use on an extension of JKT inside station telephone wiring. The tape wrappings have been removed to expose the unit, previously concealed under cover of a piece of siding.

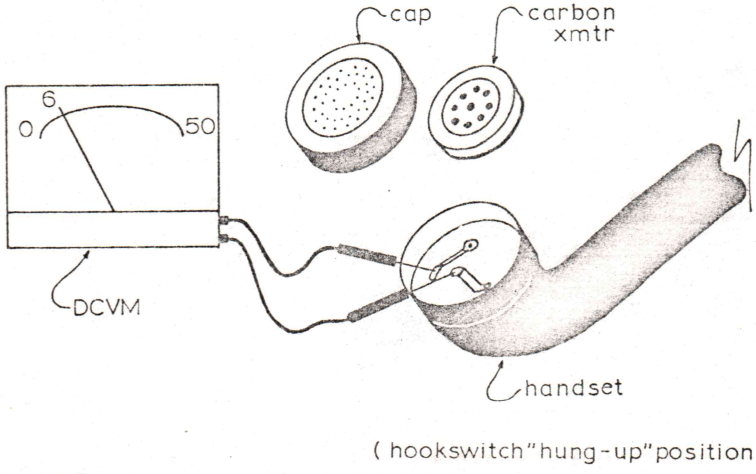


Figure 6-8. Appearance of telephone subset microphone contacts in a voltmeter test showing a third-wire "hot-mike" in use; in a normal condition there would be no voltage indication.

from an oscillator-modulated amplifier into both speakers at once. Using a separate amplifier, each lead of the telephone set mounting cord is paired with every other lead, in turn (with the handset "hung-up" on the hookswitch); if no audio is heard in any of the paired positions, the telephone has not been bypassed with the normal third-wire technique.

To check for avalanche diodes, however, a different technique must be used. The audio oscillator is left in place and a current-limited (no more than 10 ma) high-voltage (1200 volts) source of a-c is switched across every pair combination of the telephone. (For circuit, see Appendix I-10.) The manner of operation is to slowly advance the voltage control from zero through the maximum while observing a built-in milliammeter. There should be no cross-connection with any of these pair combinations, thus no current should flow in the circuit as the indicated voltage rises on the voltmeter. At some point, if an avalanche diode has been used to bypass the microphone or receiver, its breakdown voltage will be reached and the diode will suddenly become a conductor, causing a deflection of the current-flow milliammeter. The audio monitor will also now be enabled to detect the applied audio-frequency signal and will suddenly break into audible oscillation. If no such current flow occurs, the telephone set is free from bypass. The telephone set, of course, must also be checked for radiation or carrier r-f with the untuned r-f detector.

Another technique which may be used to reveal the presence of direct line taps is to feed one lead of an audio-frequency generator set on a signal of known intensity into one side of the telephone line after disconnecting the telephone set. The other lead of the a-f generator is connected to one side of a sensitive a-c voltmeter whose other lead is connected to the other side of the telephone line. Should there be no wiretap present, there will be little or no a-f indication on the a-c voltmeter. If there is a capacitance-transformer wiretap located along the line the a-c audio signal will pass directly through the capacitance-transformer circuit, causing an a-c short-circuit on the line, permitting the a-c signal to return to the a-c voltmeter. This, in turn, would create a visual response on the decibel meter.

Experimentation with this technique on telephone lines of known length, with and without wiretaps, will result in the technician being able not only to identify the presence of a tap but to estimate the distance along the line to its location.

Finally, for increased security, speech scramblers may be used with any telephone or radio system. The principle of their operation can be the inversion of different speech frequency components, band splitting, analog or time division and frequency modulation. These modified signals are sent over existing telephone lines or by radio transmission to be received by the called party who utilizes an identically coded scrambler to reconstitute the scrambled speech message. These scramblers are available from several different suppliers and are provided in single-frequency coded models or in models in which up to 25 different inversion codes may be switched at will by the using parties (MIECO). Both of these models are battery-operated and easily carried in a dispatch case. The least expensive models cost approximately $600 per pair.

SURVEILLANCE TRANSMITTERS

The presence of surveillance transmitters may be detected by r-f detectors, as has been illustrated in Figure 6-1, or all-wave surveillance receivers when they are transmitting and only by physical search when they are not radiating r-f energy. One technique is to activate an audible a-f generator through an amplifier and loudspeaker in the room to be examined. The usable r-f spectrum is then swept with an all-wave surveillance receiver such as that shown in Figure 6-7, and if such a transmitter is radiating, the generated audio modulation will be received by the surveillance receiver. The sweeping must be done in an extremely careful manner, of course, since it is quite possible in the tuning process to sweep past the oscillating transmitter without noticing it. It is a somewhat tedious process, and the technician may become bored and careless. Due to the broad tuning range of these receivers, their sensitivity is somewhat low. Most of them are on the order of 5μv or so. The cost of these

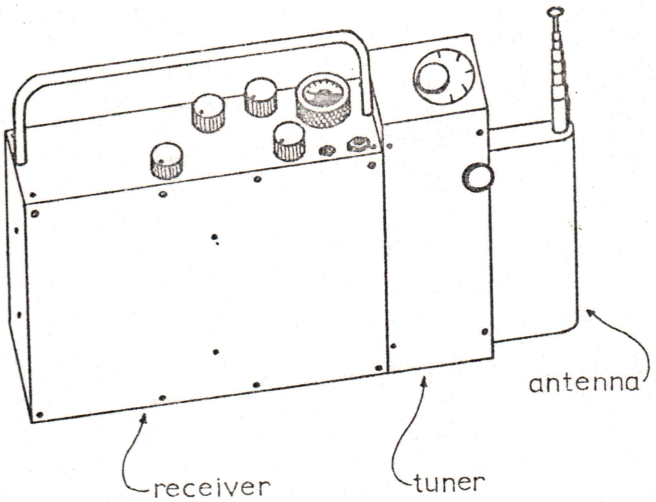
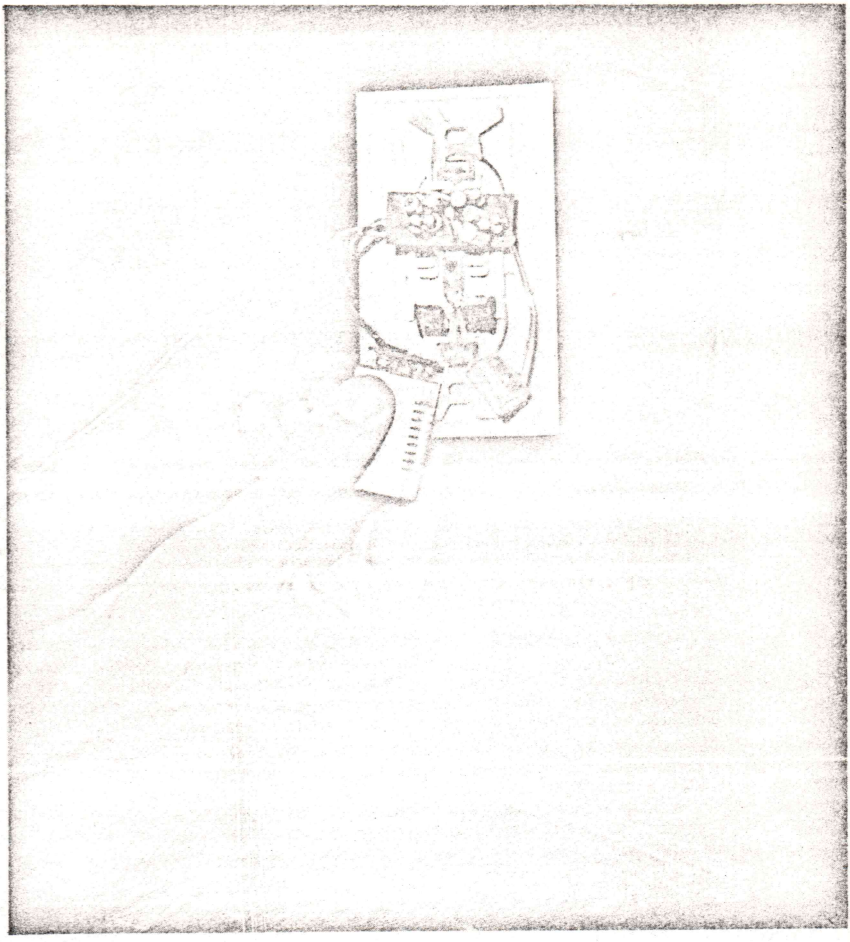


Figure 6-9. The Mason Engineering countermeasures receiver; range 2 kHz to 2 GHz, 5μv/sensitivity.

units is in the vicinity of from $2,000 to $6,000. The visual display of various forms of signal traces on an oscilloscope screen is shown in Figure 6-10 through Figure 6-14. Another method is to employ radio-frequency detectors, a form of field-strength meter. These r-f detectors may be obtained in either tuned or broadband, untuned models. The argument for the tuned models is that they are a bit more sensitive than the untuned units. The tunable models must be switched through their frequency spectrum all the while the testing is being conducted, while the untuned models need merely to be moved about the area. Some models are equipped only for meter indication, while others are fitted for earphones and oscilloscope terminations. Other models offer all features, and several units are equipped with loudspeakers which may be switched out of the circuit when it is undesirable to create feedback paths during the search. Basically, all these units are merely simple field-strength meters, bolstered by an additional stage or two of audio amplification. For added sensitivity and broadband reception, some models employ tunnel diodes as detectors. The tunable models are equipped with a number (four to six) of tuned L-C circuits at the antenna, which

A voice transmitter concealed inside the shell of a WECo 305A protector box. This unit was used to transmit conversations being held nearby on an outdoor fenced patio.

are tuned first by switching to the desired range and then by varying the capacitance of the variable capacitor in the L-C circuit. One type is shown in Figure 6-15. They, in general, cover the frequency range of from 0.15 to 500 or 10,000 MHz. The untuned models are equipped with a tapped, general purpose L-C circuit which is not variable. The frequency range capability,



A voice transmitter concealed on the reverse side of an electrical power outlet plate. These units may be battery-operated (five-day power supply), as in this case, or they may draw permanent transmitting power from the A-C line. They may also be found concealed inside multiple-outlet power plugs, in lamps and in the socket-end of electrical extension cords.

in some cases, is drawn from the high-frequency characteristics of the detector diode.

One model contains an audio oscillator which projects an audible tone in the area of its use. The tone may be picked up by the microphone of a hidden transmitter broadcast, and this

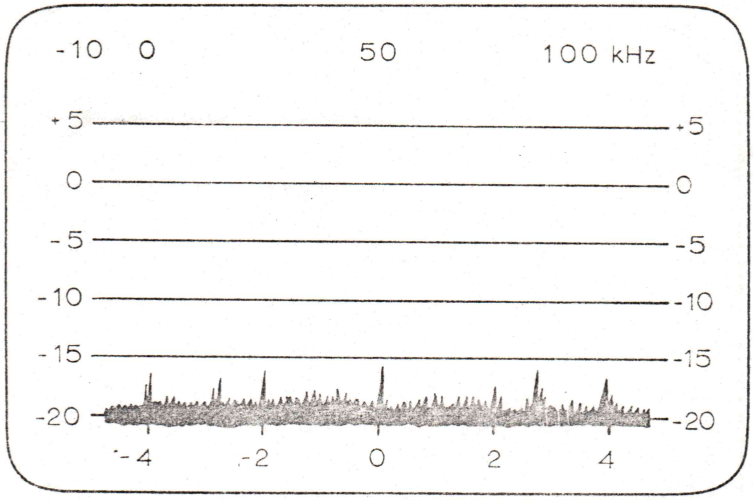


Figure 6-10. Oscilloscope screen showing electromagnetic noise ("grass") when fed by a countermeasures receiver; succeeding illustrations are of R-F signals as they would be displayed on the screen.

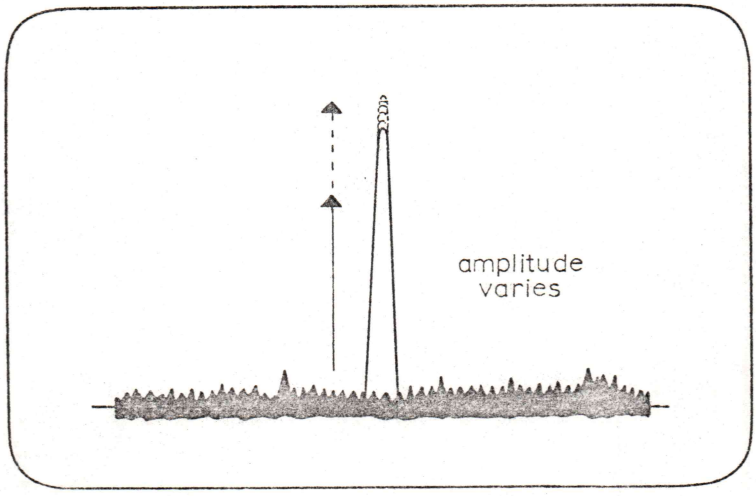


Figure 6-11. Oscilloscope screen showing A-M signal.

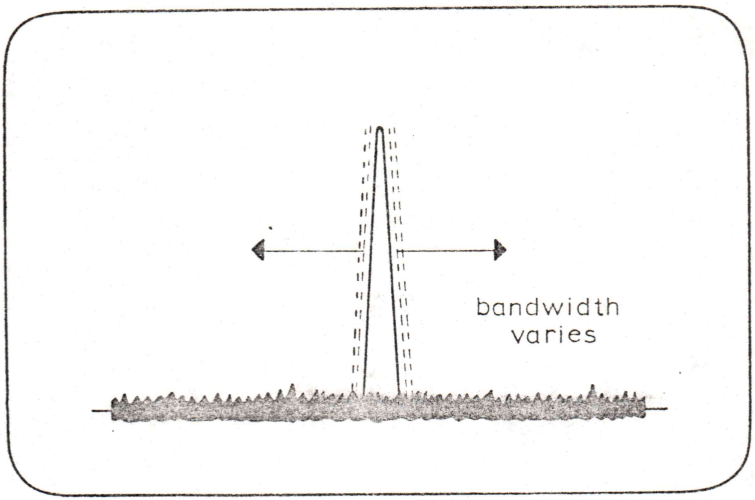


Figure 6-12. Oscilloscope screen showing F-M signal.

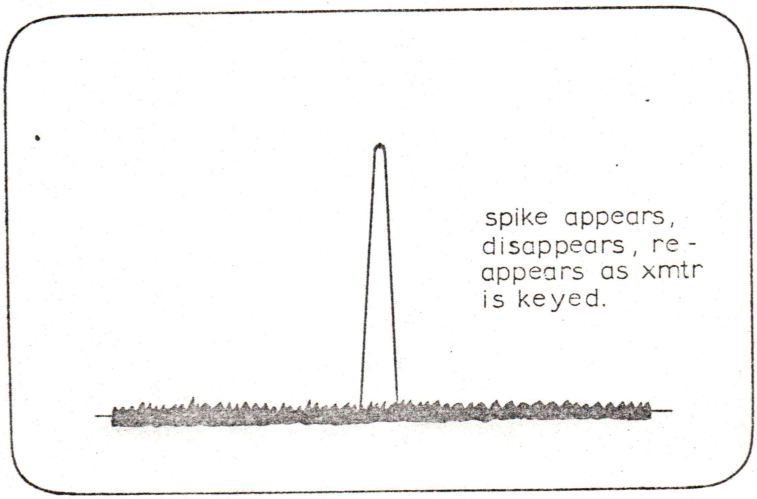


Figure 6-13. Oscilloscope screen showing C-W signal.

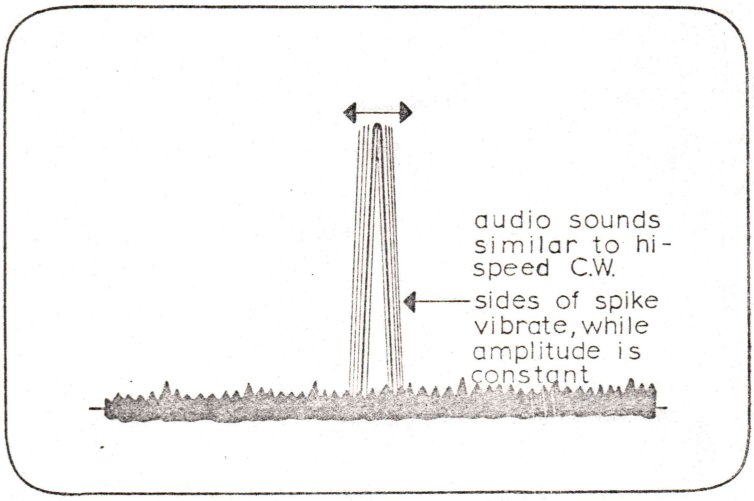


Figure 6-14. Oscilloscope screen showing FSK-TT signal.

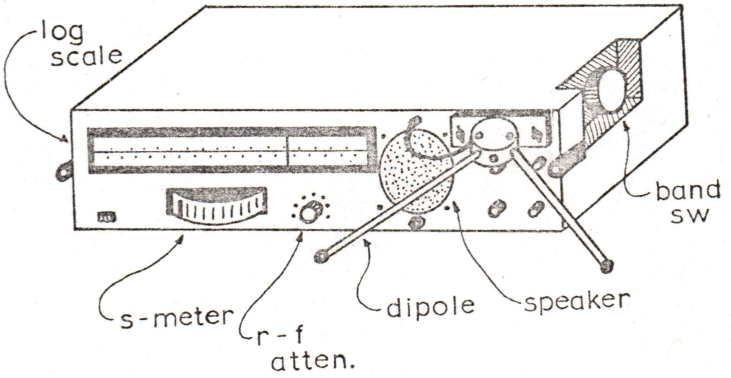


Figure 6-15. The Sprague R-F interference locator; range .54 to 220 MHz, 2μv/sensitivity.

r-f energy in turn picked up by the r-f detector which then feeds it through an amplifier to its loudspeaker. This process immediately results in uncontrolled regeneration or feedback "howl," and the transmitter is thus pinpointed.

Most of these r-f detectors are equipped with a collapsible whip antenna mounted in the same case; two other models, however, are equipped with the same antenna mounted in a wand

handle, patched to the unit by a shielded cable. This arrangement is, perhaps, more convenient to use because the search antenna must be probed into every nook and cranny in the area to be searched. The models bearing milli-ammeter or micro-ammeters give a rising deflection of the needle when the antenna is brought within range of an r-f source.

Commercial prices of these units vary between $80 and $600. In some experiments conducted by the writer, a $450-model consistently failed to detect a 5-mW transmitter, when the antenna wand was brought up to within one inch of the transmitter antenna. The same transmitter, when tested with a broadband FSM, was detected ten to fifteen feet distant. There is no question that the majority of these r-f detectors will operate in detecting the more powerful transmitters, such as those with an r-f output of greater than 100 mW, but there are far more low-output transmitters in use. If it is found that the detector may miss the lower-output transmitters, the technician would be wise to discard it, for it might be the cause of irreparable damage to believe falsely that a room was free of r-f bugs.

A capacitive, broadly-tuned wand, bearing a coil-less circuit and a silicon microwave diode, is manufactured by Continental Electronics and Sound Company (CESCO), of Dayton, Ohio, as an interference or parasitic r-f detector. One model, the MCP, is designed as an adaptor for a VOM. It is merely plugged into a sensitive VOM, and the function switch moved to the lowest milliammeter scale (0 to 50μamps is best). The wand may then be moved about the room until some indication on the VOM scale indicates the presence of r-f energy. The author tested this wand with both a 5- and a 3-mW transmitter and received indications in each case of r-f energy immediately upon entry to the room (at least a ½ inch scale deflection). With the 5 mW transmitter the VOM meter was pinned *when the wand was brought within five feet of the transmitter.* This probe, which may be used with any VOM and which is sold at retail for $13, out-performed all the other FSM r-f detectors the author has examined. When brought close to other, more powerful, r-f sources the sensitivity is decreased by switching back to the 0 to 5 mA scale. The

frequency response of this wand is from 1 kHz to 1,000 MHz. These tests, it may be noted, involved the use of an $8 Japanese VOM of 20,000 ohms-per-volt sensitivity. Transmitters tested were in the range between 30 MHz and 160 MHz.

The technique of employment of any of these r-f field detectors is to walk about the area to be checked probing along all the walls, floor and ceiling with the antenna probe. Also checked are the furniture and appliances. Telephones are checked by holding the probe near the telephone line while a call is initiated. This procedure is effective only when the transmitter is radiating energy. Remote-control transmitters, and those transmitters located in other places, using an extension microphone, must be located by physical search.

This physical search involves the removing of all electrical outlet covers and searching within the wall space, along with air and heating duct covers, thermostat boxes and radiator grilles. The same procedure is followed as was described in the section on the search for microphones. Special attention is given to telephone sets, connector blocks, protector and terminal boxes. At times, the entire wall panelling or plaster might require removal.

Line-carrier transmitters, in use, may be detected by capacitively coupling the r-f detector to the power or intercom lines to be checked.

With regard to the use of r-f detectors, it is not extremely important to know exactly what frequency on which the bug is operating but merely that there *is* one in operation.

With regard to the alternatives presented by the existence of the transmitter, a policy decision must be made whether to remove the bug, destroy it in place or permit it to operate and conduct a physical surveillance in order to determine the identity of those arriving to service or remove the device. Some idea of the values of the alternatives may be gained by an examination of the transmitter, its source of power, its monetary value and the ease of access to its hiding place. In the event that it is desired to destroy an inaccessible line transmitter, it may be destroyed by a high-voltage surge from the high-voltage destruction device previously described.

In order to ensure that any hidden transmitter that escapes detection is rendered ineffective, it is prudent to activate an r-f white-noise source of energy as a jamming device or to use a portable wide-band sweep-frequency generator of strong r-f output, such as the Jerrold 900A with D-50 detector, coupled to an antenna in the room to be protected. A supersonic generator, as shown in Figure 6-2, might also be employed to cause heterodyning in nearby microphones.

AUTOMOBILES

The searching of an automobile is similar to the searching of a room; however, there are more possible places of concealment for microphones and transmitters. The first check may be the sweep for r-f generating devices. This may best be done with an r-f probe or FSM and will also indicate the functioning of any tailing transmitter. All portions of the vehicle should be checked, including the engine and luggage compartments. Next, the space behind the dash or fascia should be thoroughly examined. Any unusual wiring should be noted and checked with a VOM and an amplifier, if appropriate. In turn, the firewall, the spaces behind the kick panels, the undersides and rear of all seats and underneath the carpeting should be examined carefully. Any unusual wiring or circuits patched off the antenna lead-in should be investigated, and stray wires hanging beneath or suspended underneath the vehicle may be thought of as possible antennas. Inside the headliner is a favorite location for hidden microphones, and that also should be checked if necessary. In some cases, microphones are hidden in the passenger compartment and fed to voice-activated, or remotely-switched, recorders hidden in the luggage compartment, under or behind the seats or behind the fascia. Shielded audio cables, bearing phone or pin plugs, may be found extending into these areas—an indication that a device *has* been present and that the transducers are probably still in place.

It has been a practice with some agencies to build-in a transmitter inside the existing broadcast-band receiver. If there is an indication that this may be the case, high-voltage may be

applied to the unit from the antenna. Some installations involve the placement of transmitters in well-concealed boxes hidden in various places in the undercarriage. If an r-f detector indicates the operation of such a device, it may be destroyed by locating and applying high-voltage to its antenna.

In the event that there is not enough time available to thoroughly check the automobile, the use of a pocket-size r-f white-noise generator is recommended. As a last resort the car radio may be played loudly during any significant conversations. Further, the automobile may be parked and the conversation perhaps may be best conducted during a stroll. It is wise to realize that devices may be installed and removed in minutes and that a locked vehicle may be entered by skilled personnel more quickly than if the owner were using his key.

DESIGN OF SECURE ROOMS

The most protective of secure rooms will be constructed with heavy concrete walls, bearing a close-knit steel mesh as a part of the wall. The mesh, for r-f shielding purposes, should be well grounded. All wiring passing into the room must be well bypassed with r-f traps. The windows, if any, should be set in steel casement and should be double-pane ("thermo-pane") glazed of conductive glass which should be grounded. The doors should be of heavy, solid-core, construction with moulded weather-strip protection, inside hinges, protected lock plates and approved "pick-proof" locks. In temporary installations, make-shift r-f protection can be afforded by the use of portable foil wall coverings made electrically common and well grounded. Metallic venetian blinds, if any, should be closed and also grounded. A radio-frequency jammer and a supersonic hetero-dyne generator may also be employed. If necessary the security of adjacent and upper and lower rooms may be ensured by their use for security personnel, after the usual countermeasures check. Again, loud music or F-M interchannel hiss may be used if no other apparatus is available.

PERSONNEL SECURITY

Of underlying importance in the electronic countermeasures area is the basic consideration of personnel security. In many cases it would be virtually impossible for anyone other than a trusted person to be able to install audio surveillance equipment in security areas. The employee background investigation is important but is only a beginning. Periodic checks on habits, credit and associations must be performed. Access to classified material and areas must be restricted to those with the appropriate security classification *and* the familiar "need to know."

A continuing program of security education should be conducted on an in-service program. Stressed here should be such matters as the importance of discussing any phase of security or confidential information only in secure areas, avoiding such locations as toilets, bars, public transportation and restaurants.

Knowledge of the identity of persons who seek information or assistance or who respond to provide some service is of the utmost in importance. Credentials should be examined carefully by persons familiar with their details and double-checked by the contact of their office of origin, if possible. Telephone contact with the verified supervisor of the individual ordinarily takes but a few minutes and may prevent a penetration of the security area. All visitors must be controlled in some way—by either pass-control or by guides. In secure areas, security personnel should accompany visitors, with technically trained security officers assigned to observe utility service personnel.

The employee should be instructed to take note of all strange or unusual contact by persons unfamiliar to him or of requests for unusual information from persons known to him who have no authorized reason for receiving such information. The employee must also be familiarized with the techniques used in recruiting informants, especially those dealing with blackmail and extortion based on deviant personal behavior.

The individual would be wise to make an effort to avoid the consistent use of one bank of public telephones. Many successful technical surveillance cases have been concluded by the monitor-

ing of certain public telephones used by subjects of the investigation. Again the use of portable electronic telephone scrambler devices may be stressed—provided that the degree of security warrants employment of such techniques.

Finally, it must be appreciated that the observance of security measures is a constant process and, if it is to be successful, must become more a state of mind. Although generally regarded as "professional paranoids," security personnel are often the last to notice security failures in their own bailiwick. It is also imperative to realize that electronic audio surveillance countermeasures can only indicate the clearance of a room or a system *at the moment of the check* and that it may not reveal past penetration. If they are to be of any continuing future benefit, countermeasure surveys must be conducted regularly, on a random selection basis, and must be supplemented by an organized, overall personnel and physical security program.

Chapter 7

THE LEGAL STATUS OF ELECTRONIC SURVEILLANCE

ENTERING THIS PHASE of the examination of electronic surveillance matters is entering a murky area indeed. Although some usage of these techniques has gained a quasilegal status when employed by law enforcement, security and intelligence agencies, the general employment of electronic surveillance devices is regarded by the courts as invasion of privacy and proscribed by law. While in many cases there has been an acceptance of such techniques in court-ordered instances and in cases involving national security, the bulk of the cases scrutinized in the harsh glare of publicity appear to wilt in their importance and, further, take on overtones of criminality. The courts have adopted a dim view of such "snooping," and evidence obtained through the use of wiretaps and audio surveillance devices has, for the most part, been suppressed. In many instances, information gleaned from operations of this nature is not intended to be presented in a court of law and is primarily used to establish a case against an individual and to reveal evidence that *may* be valid for court presentation.

Generally speaking, all "electronic invasions" may be initially regarded as being illegal until evidence is offered relating to the purported legality of the operation. These instances, it will be seen, are few and far between.

The use of radio in electronic surveillances poses a somewhat different problem. Long-standing Federal Communications Commission rulings have held that it is permissible to monitor radio communications but that it is illegal to divulge or to make use

of information gained through such monitoring. In the light of these rulings, certain wiretap and audio surveillance operations have a quasilegal veneer and become illegal when the information realized is divulged or employed for gain. In addition, the employment of many of the techniques used in electronic audio surveillance results in the violation of numerous other laws, such as burglary, housebreaking, trespass, et cetera. It is generally acknowledged that wiretapping is a refined form of eavesdropping, which itself was a crime in the time of Blackstone.[1] Laws relating to wiretapping seem little related to the eavesdropping laws which may yet be found in certain jurisdictions.

THE FEDERAL SITUATION: "NO LAW, TO SPEAK OF"

The first meaningful opinion upon wiretapping by the United States Supreme Court was a result of the investigation of the breaking of Prohibition Laws and the activity of organized crime. In the case of *Olmstead v. United States*, 1928,[2] the defendant was convicted of a conspiracy to violate the National Prohibition Act, as the result of the federal officers' monitoring his telephone calls. The *Olmstead* case, although upheld by the majority, proved useful in the establishment of legislative control over wiretapping activities. Also established was wiretapping's freedom from constitutional limitations, while the passage of legislative controls was facilitated by judicial abdication. During 1934, the Federal Communications Act was passed by Congress. Its intent was to reenact the Radio Act of 1927 to cause it to conform to wire communication and to transfer control of the Act to a new agency. It was recognized that it did not, in the main, alter the existing law. As a part of this Act is contained Section 605, the basic portion of the Act which is presented herein.[3]

> Section 605. *Unauthorized Publication or Use of Communications.*
>
> No person receiving or assisting in receiving, transmitting, or assisting in transmitting, an interstate or foreign communication by wire or radio shall divulge or publish the existence, contents, substance, purport, effect, or meaning thereof, except through authorized channels of transmission or reception, to any person other than the addressee, his agent or attorney, or to a person employed

> or authorized to forward such communication to its destination, or to proper accounting or distributing officers of the various, communicating centers over which the communication may be passed, or to the master of a ship under whom he is serving, or in response to a subpoena issued by a court of competent jurisdiction, or on demand of other lawful authorities; and no person not being authorized by the sender shall intercept any communication and divulge or publish the existence, content, substance, purport, effect or meaning of such intercepted communication to any person; and no person not being entitled thereto shall receive or assist in receiving any interstate or foreign communication by wire or radio and use the same or any information therein contained for his own benefit or the benefit of another not being entitled thereto; and no person having received such intercepted communication or having become acquainted with the contents, substance, purport, effect or meaning of the same or any part thereof, knowing that such information was so obtained, shall divulge or publish the existence, contents, substance, purport, effect or the meaning of the same or any part thereof, or use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto; Provided That this section shall not apply to receiving, divulging, publishing or utilizing the contents of any radio communication broadcast or transmitted by amateurs or others for the use of the general public, or relating to ships in distress.

A fine or imprisonment or both for the willful and knowing violation of the provisions of the Act is imposed by Section 501. It may be observed that Section 605 is described in four independent clauses, of which the second and the fourth deal with wiretapping. In the second clause, there is a requirement that two things be done. First, the message must be intercepted, and second, it must be divulged. The last clause is written more broadly, as it may be seen that it covers the instances where persons have become familiar with the message with knowledge of the interception and proscribes their use of this information. Section 605 prohibits the interception and divulgence of intrastate calls, as well as interstate messages. It has been observed that the omission of the expressed limitation to interstate and foreign communications in the second clause, while it is included in the first and third clauses, strongly suggests that the second clause is not thus limited. (Also, the feeling existed that since a

telephone line carries both interstate and intrastate calls, a person is not able to tap one without tapping the other also.)

The next notable case is *Goldman v. United States*,[4] where federal officers installed a "Detectaphone" against the external portion of the wall of the defendant's room. Through the use of this device, they were able to record all of the defendant's conversation inside the room. In addition, certain of the conversations of the defendant were made over telephone, and it was later held that the overhearing of these remarks did not constitute an interception.. In the *Goldman* case, the monitors did not obtain both sides of the telephone conversation, and from this standpoint it was felt that the monitor's relation to the telephone was not different from that of any other individual who overhears one side of a telephone call.

Other more complicated questions arise when one of the parties to a telephone conversation has arranged for a third person to monitor his telephone call with a recorder attached to the telephone line; or to listen in on an extension to the same telephone; or to overhear the telephone conversation he is carrying on with a third party with the receiver held away from his ear. In these cases the question of interception and of consent is patently present. Many cases of this nature involve the police use of an informant who previously agrees to make the monitored telephone call. In cases coming to the attention of Courts of Appeals and district courts, opinion has been divided on these issues. A question arises as to whether the monitor is hearing the voice of the person engaged in the conversation before it is received by the person hearing the conversation; thus a question might arise as to whether or not it was actually intercepted.

It is reasonable today to expect that a calling person might record or permit a third person to monitor his own telephone calls, which has become a necessary and commonly employed practice of business. It may be well to realize that the unknowing caller should realize that the recipient of the telephone call might testify personally as to the content of the call. It seems clear that in modern business practice, the caller should be aware of the widespread installation of extension telephones and should be

responsible for determining what he may safely say with this knowledge in mind. He must also realize that the called person might allow a secretary to overhear the conversation or that he might make a physical transcription of the conversation.

In the case of *Nardone v. United States,*[5] it was the government's argument that federal officers might monitor telephone calls made by the defendant and testify as to the nature of those calls, because the Government was not a "person" in the terminology of the Act. The United States Supreme Court rejected this interpretation. (Mr. J. Edgar Hoover, the director of the Federal Bureau of Investigation, wrote in May, 1940, President Roosevelt "authorized the attorney general to approve wiretapping when necessary involving the defense of the nation."[6] In October, 1941, the then Attorney General Biddle extended the right of the FBI to tap telephones by stating that the report by an agent to his superior officer did not come within the purview of Section 605.[7]) This view of the individualization of an entire enforcement organization appeared to allow the Government to tap, restricted only by the idea that the contents of the message could not be used as evidence, nor could evidence derived from the monitoring be employed.

Another question regarding Section 605 which has arisen involves the feeling by some state officials that while the federal statute prohibits interception and divulgence of both interstate and intrastate calls, it is not designed to expressly exclude state officers from its proscription. Several states established procedures to authorize wiretapping by law enforcement officers of the state.

In the case of *Benanti v. United States,*[8] the Supreme Court was unanimous in that an interception and divulgence by a New York law officer was a federal crime, despite the order of a New York court. It was determined that the constitution and statutes establishing a court-order system for the tapping of telephones in the prosecution of law enforcement cases were directly in conflict with an area preempted by Congress and were invalid. It would appear that Section 605 operates to prevent state officers from wiretapping to the same degree that federal officers are so

prohibited. It may be noted that in the twenty-five years of operation of the New York court-order system, the Federal Government has not initiated prosecution of even one state law enforcement agent for wiretapping. At that time, however, state courts still continued to issue wiretap orders, with the feeling that the situation had yet to be clarified by the higher courts.

In the *Nardone* case,[5] the Supreme Court held that federal officers may not testify to conversations intercepted by them. This became known as the Exclusionary Rule. In the second *Nardone* case,[9] there was raised a somewhat different issue. Here, it was maintained by the Government that the evidence presented against the defendant was obtained by the use of leads, which were originally obtained by monitoring telephone conversations. Here again, the United States Supreme Court held that such evidence obtained by federal agents was inadmissible—this lead evidence being, in a sense, "fruit of the poisoned tree." At this point the Supreme Court raised a reference to violation of constitutional provisions regarding search and seizure. It seems that their intention was to attempt to limit future violations by officials of the Federal Government.

Problems arising from the admission into evidence in a state court of wiretap evidence violating federal law was raised in *Schwartz v. Texas*[10] and further in *Benanti v. United States.*[8] Here, if the *Schwartz* case is valid, it is possible that a state might continue to admit evidence obtained by wiretap, and through the use of this evidence, should the state secure a conviction, it may not be attacked in federal court. Based on *Benanti,* however, it was held that a state may not affirmatively authorize such monitoring in advance. In some cases, trial justices and state courts have allowed testimony based on wiretap to be admitted, while faced with the possibility of permitting evidence of a federal crime to be admitted in their courts, although still following the rules of evidence of the state.

In the case of *United States v. Gris,*[11] a private investigator in the State of New York was charged with violating Section 605. During the trial, the telephone calls that he monitored were admitted into evidence, and his defense was that Section 605 was

violated by this admission of these calls into evidence. The Court of Appeals here denied the defendant's appeal with the opinion that a holding for the defendant would make the statute "self-emasculating." With regard to the admissibility of evidence hinging upon wiretap monitoring, ordinarily the burden is upon the defendant to show that there was a wiretap, while once the tap has been exposed, the burden of proof lies with the prosecution.

In the second *Nardone* case, Justice Frankfurter stated that the accused must be given the opportunity to prove "that a substantial portion of the proof against him was a fruit of the poisoned tree." Since the burden is upon the prosecution, if the evidence has been obtained by monitoring of communications, the Government must make a full disclosure of the communication.

In *United States v. Coplon*,[12] the trial judge had refused to allow the defendant to examine certain records of the Federal Bureau of Investigation, on the grounds that this material was sensitive and dealt with national security. The trial judge examined the records himself and had apparently arrived at the conclusion that they did not furnish the basis for the leads relating to any of the evidence presented. In this case, the Court of Appeals reversed the decision of the trial court by ruling that the Government had only two alternatives: that of disclosure of the records or of nonprosecution.

Failure in Prosecution

While a violation of Section 605 may be punished under Section 501 of the Federal Communications Act by either a fine or imprisonment, the initiation of prosecutions for such violations have been very few in number. It may be noted that the first of these involved the monitoring of telephone calls between members of the Securities Exchange Commission. During testimony taken by a Congressional investigating committee over twenty years later, it was admitted by government officers that only three prosecutions had resulted.[13] There have been some others since that testimony was presented.

It is suggested that this failure in enforcement resulted in the unusual situation where wiretaps were made legal under various state laws, in spite of their violation of Section 605 of the Federal Communications Act. This further resulted in some state legislatures enacting court-order wiretap procedures, with judges issuing many such orders and Congressional investigating committees hearing recordings of such court-ordered interceptions. In many cases the interceptions were performed by private investigators, apparently in good faith, under the existing laws of the state.

Legislative Efforts Fail

After the *Nardone* case, Congressional response to permit wiretapping by federal officers was speedy. A bill to allow tapping by government officers passed both Houses of Congress in 1938 but failed to become law due to differences between the versions approved by the separate Houses.[14]

In 1941 the Hobbs Bill and the Walters Bill were introduced in an effort to permit government wiretapping. Both of these also failed in passage.[15]

After the *Benanti* case, another bill was introduced into Congress attempting to exclude state officers from the provisions of Section 605 of the Federal Communications Act, under sharply limiting circumstances. This bill also failed in its adoption.[16]

Professor Alan Westin, of Columbia University, has written the following:

> . . . While judicial developments in the 1960's were creative and promised to be even more so in the future, legislative responses to the challenge of new technology at both state and federal levels were disappointing. . . . Less than a dozen states had enacted effectively drawn and clear statutes on the wiretapping-eavesdropping problem. At the federal level there was no legislative action on . . . the eavesdropping . . . problem.[17]

With regard to protected communications, in 1951, the United States Court of Appeals for the District of Columbia ruled that the Fifth and Sixth Amendments' guarantees to private consultation with legal counsel were violated when the Federal Bureau of Investigation monitored telephone conversations between a

defendant and her attorneys, after her indictment for treason (*Coplon* case, 1951).[18]

In 1953 the United States Court of Appeals held that the intrusion of a government agent overhearing conversations between an accused person and his attorney violated this same right to be assured of protected communication (*Caldwell* case, 1953).[19]

In the *Massiah* case, 1964,[20] the Supreme Court ruled that incriminating statements monitored by a hidden transmitter installed in the automobile of a cooperating witness and the defendant on bail for the same indictment were inadmissible, because the statements were made without benefit of counsel.

Both the *Escobido* case (1963)[21] and the *Miranda* case (1966)[22] stressed the individual's right to choose between making a statement and remaining silent, according to Supreme Court decisions in these cases. These decisions appeared to militate against the employment of electronic eavesdropping techniques on the conversations of persons in custody with visitors, confidential advisors and attorneys.

With regard to physical trespass or intrusion, in 1961, the Supreme Court found that the use of a "spike microphone," which was used by pentrating into a common wall between the defendent's apartment and that of an adjoining room used by law officers, constituted a trespass by electronic devices, thus violating the Fourth Amendment, since a warrant had not been procured.[23]

In the case of *Clinton v. Virginia* (1964),[24] the Supreme Court reversed the conviction in a similar instance where the "spike microphone" was inserted into the wall only to the depth of a thumbtack. Here it was suggested that the formal rules of property in common law, relating to trespass, might be applied where there was even a suggestion that physical intrusion had been made, thereby violating the Fourth Amendment.

In *Wong Sun v. United States* (1963),[25] and *Silverman v. United States* (1961),[23] the consensus of the Supreme Court was that conversations in and of themselves might be the object of search and seizure and, coupled with an intrusion, could suffice for employing the protection of the Fourth Amendment.

In another federal case, *Lopez v. United States* (1963),[26] the

earlier precedent of *On Lee v. United States* (1952)[27] was upheld. This case involved the concealing of a radio transmitter on the person of a federal agent whom the defendant was attempting to bribe. The consensus of the Supreme Court justices in this case was that the speaker was issuing his statements voluntarily and directly to the agent and in consequence risked that his conversation would be repeated or testified to in a court of law.

In the case of *Mapp v. Ohio* (1961),[28] it was held by the Supreme Court that the fruits of any illegal searches and seizures may not be used in evidence, and as supported by the Civil Rights Act (exemplified by *Monroe v. Pape*, 1961),[29] there is the availability of damage suits against police who initiate unlawful searches and also against the government entities employing them.

In the words of Professor Westin

> . . . Thus, the Court seems on the brink of a landmark ruling defining a comprehensive, positive right of privacy from unreasonable surveillance. The rising concern over surveillance devices, alongside continued inaction by Congress on electronic eavesdropping, increases the likelihood that such a ruling will come soon.[30]

THE SITUATION IN THE STATES

In many of the states, laws regulating or prohibiting wiretapping were enacted before the entry of the Federal Government upon the scene. Many of these were introduced in the early 1900's. Several of these early statutes merely added telephone lines to already existing statutory protection of the privacy of telegraph messages. Due to the form of some of the state statutes and their independent development, the problem of what person might authorize an interception is unclear. While Section 605 requires consent of the sender, many state laws are foggy on this point. At one time California held that it was necessary to obtain the consent of both the subscriber and the telephone company, while New York courts, for many years, held that a subscriber was authorized to place a wiretap on his own telephone, whether or not he was a party to the call.

At this point it appears to be established that when one of the parties to the call consents to the overhearing of the call, it is sufficient to remove it from the protection of Section 605.

California

The original California statute proscribing wiretapping was enacted in 1905 as an amendment to the antitelegraph-tapping law of 1872.[31] Although a California statute authorizing the installation of "dictagraphs" by police and law enforcement officers existed, no such exception was included in the California wiretapping statute—Section 640 of the Penal Code.

In *People v. Cahan,* in 1955,[32] the California courts began to be concerned with the exclusion of evidence because of considerations of the manner in which it was obtained. The *Cahan* case dealt with evidence obtained by unreasonable search and seizure. California's statute was a combination of terms which were ambiguous or inapplicable to the monitoring of telephones. It was based on an adaptation of California's earlier laws relating to the interception of telegraph messages. This statute required that the tapping be done "willfully and fraudulently, or clandestinely" or be "unauthorized." There existed some confusion over the exact intent and application of these terms.

In *People v. Trieber,*[33] the word "unauthorized" entails the consent of the telephone company as well as the subscriber.

In *People v. Channel,*[34] the evidence procured by monitoring was held to be admissible because a participant in the conversation had consented and there was no unauthorized or clandestine taking of the information.

In *People v. Malotte,*[35] the requirement of telephone company approval was placed in further doubt. In this case, police vice squad officers who suspected the defendant of vice activities rented a hotel room, placed an induction coil on the room telephone and recorded a conversation with the defendant, wherein the defendant agreed to furnish two girls to visit the room for prostitution purposes. In this case the conviction of the defendant was affirmed and the opinion was that the *Channel* case had established a rule of sufficiency regarding the consent of one party to the telephone conversation.

As the result of *People v. Cahan,* California courts have extended the protection of the Exclusionary Rule allowing a person to object to evidence obtained through unreasonable search and seizure, although he may not have been the original subject of these illegal actions.

The punishment of the violation of California's Penal Code Section 640 was imprisonment not exceeding one year and/or a fine not exceeding $5,000.00. This one year punishment allowed by California under this statute is the maximum most frequently encountered among the state statutes. By the statutes of 1967, Chapter 1509, California repealed Section 640 and others dealing with eavesdropping, or the invasion of privacy, and adopted a new chapter entitled Chapter 1.5, Invasion of Privacy.[36]

The thinking behind the new chapter is set out in Section 630, the Declaration of Policy, which is as follows:

> The Legislature hereby declares that advances in science and technology have led to the development of new devices and techniques for the purpose of eavesdropping upon private communications, and that an invasion of privacy resulting from the continual and increasing use of such devices and techniques has created a serious threat to the free exercise of personal liberties and cannot be tolerated in a free and civilized society. The Legislature by this chapter intends to protect the right of privacy of the people in this State. The Legislature recognizes that law enforcement agencies have a legitimate need to employ modern listening devices and techniques in the investigation of criminal conduct and the apprehension of lawbreakers. Therefore, it is not the intent of the Legislature to place greater restraints on the use of listening devices and techniques by law enforcement agencies than existed prior to the effective date of this chapter.

At the same time that the new sections, numbered Section 630 through Section 637.2, were enacted, the legislature repealed all of the other miscellaneous prohibitions against eavesdropping, certain of which permitted law enforcement officers to install "dictagraphs" in any premises upon order of the District Attorney or chief of the police agency. Due to the wording of the new sections, it is unclear at this time just what monitoring is permissible.

Section 631 of the California Penal Code defines what formerly was covered by Section 640, and reads as follows:

> (a) Any person who, by means of any machine, instrument, or contrivance, or in any other manner, intentionally taps or makes any unauthorized connection, whether physically, electrically, acoustically, inductively, or otherwise, with any telegraph or telephone wire, line, cable, or instrument, including the wire, line, cable, or instrument of any internal telephonic communications system, or who willfully and without the consent of all parties to the communication, or in any unauthorized manner, reads, or attempts to read, or to learn the contents or meaning, report or communication while the same is in transit or passing over any such wire, line, or cable, or is being sent from, or received at any place within this State; or who uses, or attempts to use, in any manner or for any purpose, or to communicate in any way, any information so obtained, or who aids, agrees with, employs, or conspires with person or persons to unlawfully do, or permit, or cause to be done any of the acts or things mentioned above in this section, is punishable by a fine not exceeding two-thousand five-hundred dollars ($2,500), or by imprisonment in the county jail not exceeding one year, or by imprisonment in the state prison not exceeding three years, or by both such fine and imprisonment in a county jail or in the state prison. If such person has previously been convicted of a violation of this section or Section 632 or 636 he is punishable by fine not exceeding ten-thousand dollars ($10,000), or by imprisonment in a county jail not exceeding one year, or by imprisonment in the state prison not exceeding five years, or by both such fine and imprisonment in the county jail or in the state prison.

The (b) and (c) portions of this section apply respectively to exemptions for public utilities in the testing of lines; to any telephonic communications system used for communication exclusively within the state, county, city and county, or city correctional facility; and no evidence obtained in violation of this section shall be admissible in any judicial, administrative, legislative or other proceeding except as proof in an action or prosecution for the violation of this section.

Section 632 of the California Penal Code deals with the prohibition of eavesdropping on confidential communications. Pertinent portions are included here:

> (a) Every person who, intentionally and without the consent of all parties to a confidential communication, by means of any electronic amplifying or recording device, eavesdrops upon or records such confidential communication, whether such communication is carried on among such parties in the presence of one another or by means of a telegraph, telephone or other device, except a radio, shall be punishable by fine not exceeding two-thousand five-hundred dollars ($2,500), or by imprisonment in the county jail not exceeding one year, or by imprisonment in the state prison not exceeding three years, or by both such fine and imprisonment in the county jail or in the state prison. . . .

There follow several subsections defining "person," "confidential communication," the prohibition against the use of information gathered in violation of this section in evidence, the exemption of public utilities engaged in testing operations and the exemption of the use of hearing aids and similar devices by persons afflicted with impaired hearing.

Section 633, which follows, is an interesting anomaly, since it appears to permit law enforcement officers to intercept certain communications. Its language follows:

> Nothing in Section 631 or 632 shall be construed as prohibiting the Attorney General, any district attorney, or any assistant, deputy, or investigator of the Attorney General or any district attorney, or any officer of the California Highway Patrol, or any chief of police, assistant chief of police, or policeman of a city or city and county, any sheriff, undersheriff, or deputy sheriff regularly employed and paid as such by a county, or any person acting pursuant to the direction of one of the above-named law enforcement officers acting within the scope of his authority, from overhearing or recording any communication which they could lawfully overhear or record prior to the effective date of this Chapter. Nothing in Section 631 or 632 shall be construed as rendering inadmissible any evidence obtained by the above-named persons by means of overhearing or recording any communication which they could lawfully overhear or record prior to the effective date of this Chapter.

Section 633.5 of the California Penal Code grants further exemptions from the invasion of privacy law:

> Nothing in Section 631 or 632 shall be construed as prohibiting one party to a confidential communication, from recording such communication for the purpose of obtaining evidence reasonably

believed to relate to the commission by another party to such communication of the crime of extortion, kidnapping, bribery, any felony involving violence against the person, or a violation of Section 653m (Making Annoying or Obscene Telephone Communication), and nothing in Section 631 or 632 shall be construed as rendering inadmissible in a prosecution for extortion, kidnapping, bribery, any felony involving violence against person, or a violation of Section 653m, or any crime in connection therewith, any evidence so obtained.

It is interesting to note here that Section 633.5 apparently allows one party to a confidential communication to record the conversation in cases involving suspicion that the other party to the conversation is involved in certain crimes. Section 633, on the other hand, apparently allows law enforcement officers to overhear or record any communication which they could lawfully overhear or record prior to the effective date of this chapter. Whether this permission extends to the previous mystical application of Section 640 and the permissible "dictagraph" section, Section 653h, is unclear, since these sections were repealed at the time of the adoption of the Statutes of 1967.

Section 634 of the California Penal Code makes it a crime for any person to trespass on property for the purpose of committing any act or attempting to commit any act in violation of Section 631, 632 or 636 and establishes appropriate punishment for such violation.

Section 635, dealing with the sale of eavesdropping devices, seems to clearly prohibit the traffic in electronic eavesdropping devices without exception:

(a) Every person who manufactures, assembles, sells, offers for sale, advertises for sale, possesses, transports, imports, or furnishes to another any device which is primarily or exclusively designed for or intended for eavesdroping upon the communication of another is punishable by a fine not exceeding two-thousand five-hundred dollars ($2,500), or by imprisonment in the county jail not exceeding one year, or by imprisonment in the state prison not exceeding three years, or both such fine and imprisonment in the county jail or in the state prison. . . .

There is no provision here for the sales to, or possession of these devices by, law enforcement agencies whose authorization

to use them has been implied above in Sections 633 and 633.5.

Section 636 deals with the prohibition against monitoring or recording a conversation between a person who is in the physical custody of a law enforcement or other public officer or who is on the property of a law enforcement or other public agency and such person's attorney, religious advisor or licensed physician, and it makes the violation of this section a felony.

Section 637 deals with the willful disclosure of any telegraphic or telephonic message and is as follows:

> Every person not a party to a telegraphic or telephonic communication who willfully discloses the contents of a telegraphic or telephonic message, or any part thereof, addressed to another person, without the permission of such person, unless directed so to do by the lawful order of a court, is punishable by imprisonment in the state prison for not exceeding five years, or in the county jail not exceeding one year, or by fine not exceeding five-thousand dollars ($5,000), or by both fine and imprisonment.

Here again is avoided any reference to authorization of law enforcement officers and agencies in dealing wtih permissible monitoring and recording.

Section 637.1 deals with the unauthorized opening of telegraphic or telephonic messages and the fraudulent representation for procurement of these messages, while Section 637.2 provides injunctive relief for actual damages due to persons who have been injured by a violation of this chapter.

Additionally, in California's Public Utilities Code, may be found the following statutes bearing on the safeguarding of communications[37]:

> Section 7903. *Use or Appropriation of Information From Private Messages, Penalty.*
>
> Every agent, operator, or employee of any telegraph or telephone office, who in any way uses or appropriates any information derived by him from any private message passing through his hands, and addressed to any other person, or in any other manner acquired by him to reason of his trust as such agent, operator, or employee, or trades or speculates upon any such information so obtained, or in any manner turns, or attempts to turn, the information so obtained to his own account, profit or advantage, is

punishable by imprisonment in the state prison not exceeding five years, or by imprisonment in the county jail not exceeding one year, or by fine not exceeding five-thousand dollars ($5,000), or by both such fine and imprisonment.

Section 7905. *Records of Discovery of Devices for Overhearing Telephone Conversations.*

The Public Utilities Commission shall issue regulations requiring every telephone corporation subject to its jurisdiction to maintain complete records on all instances in which its employees discover any device installed for the purpose of overhearing communications over the lines of such corporation and all instances in which such employees reasonably believe and report to the corporation their belief that such device is installed or has been installed but has since been removed.

Section 7906. *Privacy of Communications; Investigation.*

The Public Utilities Commission shall regularly make inquiry of every telephone corporation under its jurisdiction to determine whether or not such corporation is taking adequate steps to insure the privacy of communications over such corporation's telephone communication system.

Note here that a requirement is placed on the telephone company to maintain complete records relating to taps, or evidence thereof, found by their employees, and responsibility is outlined for the company to take "adequate steps to insure the privacy of [their] communications . . ." In some states these requirements are a part of the penal law. It is interesting to note their inclusion in the Public Utilities Code. It is possible that more attention to such matters may be afforded since the Public Utilities Commission oversees the telephone companies' franchises.

New York

As a result of extensive hearings by a legislative committee formed as a logical consequence of the Broady wiretap inquiries, major legislative changes in New York's wiretapping law occurred during 1957 and 1958.[38, 39] New York's general wiretapping law, before adoption of the 1957 and 1958 changes, was an adaptation of their old malicious destruction statute. Officials in New York, who had indictments brought against them in 1916, had their

cases dismissed by the hearing officer who mentioned specifically the operations of the wiretapping unit of the Police Department of the City of New York.[40]

Section 813a of the Code of Criminal Procedure was adopted in 1942.[41] It is apparent that this legislation codified many of the actual practices in that era. This statute required that an oath or affirmation must be made by a law officer that there is reasonable grounds to believe that evidence of a crime will be obtained by such monitoring and the affidavit must identify the specific telephone to be monitored and describe the individual whose conversations are to be intercepted and the purpose for engaging in this activity. The statute also specified the judges who have the ability to issue the wiretap orders and defined who must make the affidavit. It also gave the judge the specific authority to conduct examination of the applicants and other persons in making the decision whether to issue a wiretap order; placed a maximum of six months life upon the order, unless renewal was granted; required the judge to retain a copy of the order and to deliver a copy of the papers and the original order to the applicant.

In another New York case, *People v. Appelbaum*,[42] it was determined that the subscriber to a specific telephone might authorize a wiretap upon that phone and that conversations occurring through the use of that phone might be recorded whether or not the subscriber was one of the parties to the calls. This case permitted the existence of private wiretappers in the State of New York. In many divorce cases the question of who actually was the subscriber was a question not attempted to be answered.

Another case,[43] involving a failure in prosecution for wiretapping, resulted in the enactment of a "possession" statute likened to the statute regarding the possession of burglar tools. This statute made it a crime to possess instruments used for unlawful wiretapping.

A series of scandals involving wiretaps resulted in a change in the Code of Criminal Procedure and changed the effective

period of the wiretap authorization from six months to two months. Also added was Section 813b, wherein a police officer would be guilty of a felony for intercepting, overhearing or recording a telephone communication to which he is not a party when he does not have the consent of one of the parties or a court order. The punishment for this offense is set at not more than two years.

Also, a new section, Section 738(1) of the Penal Law, furnishes a definition of an unlawful wiretapper:

> . . . a person: (1) not a sender or receiver of a telephone or telegraph communication who willfully and by means of instrument overhears or records a telephone or telegraph communication, or who aids, authorizes, employs, procures, or permits another to so do, without the consent of either a sender or receiver thereof. . . .

It may be seen in the light of this law that an individual may make a recording of his own telephone call and that he may record or monitor the calls of other persons if he has the consent of one of the parties of the conversation. The language of the statute is interesting here, since the use of the words "sender" or "receiver" are separate and distinct from the term "subscriber" used in the *Appelbaum* case. This change in New York's law is in accordance with the federal rule set in the case of *Rathbun*.[44]

The exception of telephone companies and normal operations of testing and maintenance of the communications system is covered by Sections 739, 740 and 741, which also define the word "person" to specifically exclude law enforcement officers acting lawfully, in their official capacities.

Section 742 defines the crime of possession of instruments for wiretapping and is worded so that it includes all instruments for eavesdropping, rather than limiting itself as did the earlier statute.

Section 743 deals with unlawfully obtaining information from employees of telephone companies and the wrongful divulging of such messages by employees of the company. It excepts messages dealing with the perpetration of certain crimes. In addition, the statute covers the unlawful obtaining of information relating to telephone company premises or equipment. Also created is a

lephone company employees to report premises in
ıones are used to carry on unlawful activities.
744 requires telephone company employees to report
eavesdropping, coming to their attention, to law
agencies.
745, in reference to the court orders issued under
., makes it a misdemeanor for a person to unlawfully
lications for wiretap orders and any information about
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o the Code of Civil Procedure is Section 345a, a
ıgainst introducing into a civil action any evidence
violation of Section 738 of the Penal Law and Section
Code of Criminal Procedure. Exception is made for
or administrative actions by or on behalf of govern-
cies.[45]

ıois State Legislature in 1957 enacted a compre-
ronic eavesdropping statute to include wiretapping.[46]
1957 statute, the Illinois law outlawed a wiretap
lfully and maliciously." To that time there were no
reported under that statute.[47] The new anti-eaves-
tute of Illinois prohibits eavesdropping if it is done
ısent of any party thereto."
states this wording has been held to mean that the
ny party to the conversation would be sufficient to
e. Illinois' present statute provides that overhearing
e may be punished separately. The law also encom-
preclusion of evidence obtained in violation of its
les for injunctions and actual punitive damages; and
uirement of the telephone company to provide elec-
llance countermeasures.

in Louisiana is relatively simple in that it states:

> son shall tap or attach any devices for the purpose of
> on wires . . . without the consent of the owner. . . .[48]

ention of this statute to exclude law enforcement

officers. Thus, there are no evidentiary problems regarding the Exclusionary Rule. The violation of Louisiana's statute by private persons amounts to a misdemeanor which is punishable by a maximum imprisonment of three months or a maximum fine of $300.

Massachusetts

Massachusetts' statute prohibits the use of wiretapping for the purpose of procuring any information concerning any official matter or to injure another person, except when it is authorized by the attorney general or by a district attorney. The Massachusetts statute is the only state law wherein is established a procedure for authorization by the legal officer of the state or district. It is sufficiently broad to allow the authorization of a wiretap by a private party. The use of wiretaps in Massachusetts by the police without authorization by the attorney general or the district attorney probably would not be covered by this statute because of the limitation regarding the injury of another.[49]

Nevada

During 1957 Nevada enacted a new wiretap statute, which is similar to the New York court-order method. In this case the order may be issued under circumstances where ". . . there are reasonable grounds to believe that the crime of murder, kidnapping, treason, sabotage or a crime endangering the national defense has been committed or is about to be committed. . . ." It also requires that grounds must exist to believe that the evidence will be obtained by the wiretap and that no other suitable means are reasonably available. The Exclusionary Rule in the Nevada statute applies to *all* proceedings for evidence which may be obtained in violation of the anti-wiretap act. The Nevade law limits a renewal of the wiretap order to thirty days and fails to require telephone company employees to report violations or to search out suspected cases of unlawful wiretaps. It also imposes prohibition on other forms of eavesdropping and provides that the initial period of the court order is for a sixty-day period.[50]

New Jersey

New Jersey's anti-wiretap statute prohibits divulgence as well as tapping and has been recognized as an evidentiary statute. It has been held that a recording made by one of the parties to the conversation is not covered by the law and that the law is expressly intended to prohibit willful and malicious tapping.[51]

Pennsylvania

Also in 1957, Pennsylvania's legislature enacted a prohibitory statute against wiretapping.[52] The elements of the law are that it became a crime to intercept a telegraph or telephone communication without the consent of the parties thereto; to install or employ any instrument for overhearing or recording such telephone or telegraph communication; or the divulgence or the use of the content of such intercepted communication. Here the legislators apparently were aware of the problems arising from the federal statute, because the consent of both parties to the communications is required, and governmental employees were included in the act. The definition of divulgence of messages includes the divulgence of a message to a fellow employee or official of the Government and it was specifically included that evidence obtained as a result of such unlawful interception was inadmissible in a court of law, except in a suit or prosecution for a violation of the act itself.

Under Pennsylvania's law the victim of an unlawful interception is given a civil remedy and treble damages. Minimal damages of $100 and reasonable attorney fees are allowed.

OTHER AUDIO SURVEILLANCE

Mentioned earlier in this treatment of the laws relating to audio surveillance, wiretapping is regarded as a specialized type of eavesdropping. Most courts and legislatures are of the opinion that the individual's right of privacy was not in danger where one of the parties to a conversaion had given permission to a third party to overhear it. In general, the rules of evidence bolster this position with the exception of limitations pertaining to the confidentiality of privileged communications. According to the

rules of evidence, a party to a conversation may testify and may even be forced to testify with regard to the conversation when the person testifying is a party to the conversation and the opposing side desires to adversely introduce the statement. The exception of the privileged communication applies here also.

The background of eavesdropping and its development as a crime is based in the early common law. The latest reported English case occurred in 1930, but it has been mentioned in the legal textbooks of Blackstone and others. Blackstone, in his Commentaries, gave the following definition of the offense:

> Eaves-droppers, or such as listen under walls or windows, or the eaves of a house, to hearken after discourse, and thereupon to frame slanderous and mischievous tales, are a common nuisance and are punishable at the court-leet; or are indictable at the Sessions, and punishable by finding sureties for their good behaviour.[1]

It may be noted that the act committed be "habitual," similar to other public nuisance offenses, and that indictments alleging only one offense are defective.

The federal law, it may be observed, includes no common-law crimes and, prior to 1968, no general federal eavesdropping statute existed; as will be discussed later, a new eavesdropping statute specifically directed against eavesdropping through the use of radio devices was enacted by the Federal Communications Commission in 1966. Most of the law existing at the federal level arises as a result of problems of evidence.

In the *Olmstead* case, evidence obtained by wiretapping was felt to be a violation of the Fourth Amendment, although the conviction was upheld because there was no "technical trespass." The Supreme Court, who recognized wiretapping to be a "dirty business," apparently felt that the act was morally bad. In affirming the certification, the majority decided that wiretapping did not constitute unreasonable search and seizure and apparently based this on three factors: in that case, there was no seizure of a thing of material value or of a person; in that case, apparently the speaker intended to transmit his voice outside of the room involved; and finally there were no acts amounting to trespass upon the defendant's property.

In the case of *Goldman v. United States*,[53] problems arose since federal officers entered the defendant's office to install a "dictaphone." In addition to this technique, the federal agents employed a "Detectaphone" against the outer wall of his office. The installation of the "dictaphone" involved a physical trespass on the defendant's premises, while the "Detectaphone" did not involve such a physical trespass. It was reported that the "dictaphone" was not operable and that the defendant's conversations were overheard and subsequent notes made of these through the use of the "Detectaphone," used on the outside wall, and that this testimony was properly admitted at the trial.

In the case of *On Lee v. United States*,[27] an informant entered the laundry run by On Lee and engaged On Lee in a conversation. Concealed upon the body of the informant was a miniature radio transmitter, which transmitted the conversation to an agent of the U. S. Treasury located at a distant point. It was stated that no recording was made of the conversation with On Lee, but the Treasury agent was permitted to testify as to the purported conversation. The conviction in this case was affirmed by the Supreme Court.

A somewhat different case was presented in *People v. Irvine*,[54] where it was determined that if the officers commit a trespass, the ensuing eavesdropping then constitutes an unreasonable search and seizure. In the *Irvine* case, law enforcement officers produced keys to the front door of Irvine's home. They then entered surreptitiously and installed a microphone by drilling holes in his roof to route wires to a distant listening post. When it was determined that the results from this first entry were unsatisfactory, the officers committed a second trespass to relocate the microphone to Irvine's bedroom. The results of the relocation of the microphone in the bedroom in this case were significantly better and at an appropriate point the police officers re-entered Irvine's house, using their passkey, arrested Irvine and seized the evidence of his crime. The Supreme Court was unanimous in terming this set of circumstances as a violation of the defendant's civil rights and an unreasonable search and seizure.

In *Katz v. United States*,[73] the sanctity of the public telephone

booth was questioned when it was revealed that agents planted a transmitter in a telephone booth used by Katz to monitor his side of the conversation. The feeling of the court was that there are certain places that a citizen may reasonably expect to be private and that one of these is a public telephone booth. The court, however, did not prohibit the use of eavesdropping devices planted on the persons of informants. In *United States v. Kaufer,*[74] wherein an I.R.S. agent employed a radio transmitter in a briefcase, the appellate court ruled that because one of the parties to the conversation gave his consent, it was admissible. Their feeling was that the principle in *Katz* applies only to "no party" consent. In a similar case, *Koran v. U.S.,*[75] the appellant made a point of his desire not to expose his words to the public. The court stated, however, ". . . that this fact alone does not suffice for no criminal desires exposure of his surreptitious activity. The crucial fact here is that the appellant knowingly took the risk that the conversants might expose his statements. . . ."

On the other side of the coin, in an effort to reduce unlawful bugging, in 1969, the Attorney General of the United States authorized the FBI to seize wire or oral communication intercepting devices under the provisions of Section 2513 of the Criminal Code (Title 28, Code of Federal Regulations, Part 8).[76]

In a decision rendered on April 5, 1971, the Supreme Court, in partial response to a United States Justice Department query, gave government agents authorization to send transmitter-carrying informants into the homes of narcotic suspects to record the subsequent conversations and to use those recordings as evidence in further criminal proceedings.[77] This decision was received warmly by the law enforcement community.

On April 8, 1966, the Federal Communications Commission[55] amended its rules to prohibit eavesdropping by means of radio.

> 1. Part 2 is amended by adding a new Subpart H to read as follows:
>
> Subpart H—*Prohibition Against Eavesdropping.*
>
> Section 2.701. *Prohibition Against Use of a Radio Device for Eavesdropping.*
>
> (a) No person shall use, either directly or indirectly, a device

required to be licensed by Section 301 of the Communications Act of 1934, as amended, for the purpose of overhearing or recording the private conversations of others unless such use is authorized by all of the parties engaging in the conversation.

(b) Paragraph (a) of this Section shall not apply to operations of any law enforcement officers conducted under lawful authority.

2. Part 15 is amended by adding a new section to Subpart A to read as follows:

Section 15.11. *Prohibition Against Eavesdropping.*

(a) No person shall use, either directly or indirectly, a device operated pursuant to the provisions of this part for the purpose of overhearing or recording the private conversation of any law enforcement officers conducted under lawful authority.

3. Subpart E of Part 15 is amended by adding a new section to read as follows:

Section 15.220. *Eavesdropping Prohibited.*

As provided in Section 15.11 the use of a low-power communications device for eavesdropping is prohibited.

How this may be viewed in the light of *United States v. Kaufer*[74] (wherein the CA approved the I.R.S. use of a briefcase transmitter) remains to be seen.

In an annual report issued on January 3, 1967, by the Federal Communications Commission, the Chairman Rosel H. Hyde stated

> Eight reports involving possible violation of Section 15.11, Prohibition Against Eavesdropping, were investigated since the rules became effective April 8, 1966. Most violations were apparently made in an effort to obtain evidence for domestic relations proceedings.[56]

In an effort to obtain further information on these reported violations Robert M. Brown, author of *The Electronic Invasion*,[57] corresponded with FCC spokesman, Ben Waple. The information requested by Brown regarding these violations was refused by Mr. Waple, who stated that such information was considered by the FCC to be confidential.[58] It is unknown whether any prosecutions or convictions resulted from these alleged violations mentioned in the FCC annual report.

At this point it would not seem unreasonable, in light of the FCC's reluctance to even discuss the cases, to assume that no

convictions or prosecutions occurred. It is well-known that the Government has *continuously* employed surveillance radio transmitters for the past twenty-four years without the hindrance of being required to observe its own laws.

As has been mentioned earlier in this section, the previous California statute (Section 653h, California Penal Code) prohibited the installation of a "dictagraph" in a specified number of locations and vehicles without the consent of the "owner, lessee or occupant." Exception in this statute was made for "regularly salaried peace officer(s)" acting with the approval of the head of the department or of the district attorney, when it became necessary in the detection of crime or apprehension of criminals. There were many ambiguities in this statute. Problems arose relating to the consent of the owner, should there be a lessee in evidence. The instrument referred to in the statute —the "dictagraph"—did not appear to encompass the use of a subminiature recorder or a radio transmitter as was used in the case of *On Lee* and many of the other subminiature devices used in electronic surveillance. This writer could find no record of where this "dictagraph" was defined—although it probably refers to a wired microphone-amplifier system.

The new chapter in the California Penal Code dealing with invasion of privacy seems to prohibit by anyone those activities permitted or ignored by the previous law, although there is a confusing section which states that it is the intention of the act not to prohibit law enforcement officers from engaging in any activity which was permitted them prior to the passage of the present act. The changes in the California statute were partially stimulated by a detailed report of the California legislative committee, which offered the following conclusion, when recommending the prohibition of eavesdropping on privileged communications, when one party was in the custody of a law enforcement agency:

> In summary, the implicit physical restrictions of the present telephone system to its actual lines indicates present statutory provisions on wiretapping have generally been capable of keeping abreast of scientific developments in that field thus far. The

> law of bugging, however, is in need of clarification in a number of respects, and will have to be frequently reviewed in the light of developing technology.[59]

In 1957 the State of New York re-defined its eavesdropping statute to include wiretapping and recording or monitoring the deliberations of a jury, as well as the recording or overhearing of conversation or discussion between persons without the consent of a party to such conversation or discussion. The 1957 New York act excluded law enforcement officers acting lawfully in their official capacity in the investigation, detection or prosecution of crimes; however, in 1958, amendments were made to this law to include police officers within the prohibition and to broaden Section 813a of the Code of Criminal Procedure, regulating the issuance to law enforcement officers of court orders permitting eavesdropping. Additionally, emergency eavesdropping was permitted without a court order, should there not be time to obtain one. In any case, the order must be requested within twenty-four hours of the time the eavesdropping is begun.[60]

The State of Nevada also enacted an eavesdropping statute, which is shown below:

> . . . Except as otherwise provided in Section 7, no person shall intrude upon the privacy of other persons by surreptitiously listening to, monitoring or recording or attempting to listen to, monitor or record, by means of any mechanical, electronic or other device, any private conversation engaged in by such other persons, or disclose the existence, contents, substance, purport, effect or meaning of any such conversation so listened to, monitored or recorded, unless authorized to do so by one of the persons engaging in the conversation.[61]

It may be noted that this Nevada statute applies specifically to eavesdropping by law enforcement officers. The Section 7 mentioned in the section quoted above permits such overhearing under a court order, which is similar to that employed by New York. However, it is limited to cases involving murder, kidnapping, treason, sabotage or crime endangering the national defense.

The Illinois statute of 1957[46] has been discussed in the previous

material on wiretapping and is mentioned here because the entire act is pertinent equally to both electronic eavesdropping and wiretapping. It was noted that all electronic eavesdropping is prohibited, with no exclusion for law enforcement officials.

Notable Civil Cases

Several civil cases involving the use of listening devices by citizens encroaching upon the rights of other citizens are of interest. In *Roach v. Harper* (1958),[62] a landlord installed a listening device in the apartment of his female tenant and it was alleged that the device was employed by the landlord for seven months to monitor her confidential conversations. The lower court dismissed the suit for damages; however, the Supreme Court of West Virginia reversed this dismissal and decided that the injury to privacy devolved upon the intrusion itself.

A similar case, *Hamberger v. Eastman* (1964),[63] in New Hampshire involved again a landlord who placed a listening device in the bedroom of a house that he rented to a husband and wife. The landlord connected hidden wires from the complainants' house to his own house adjacent to the rented unit and caused the husband and wife great distress, embarrassment and mental suffering upon discovering the electronic trespass. The New Hampshire Supreme Court ruled that the plaintiffs were entitled to recovery for this electronic intrusion on their privacy. The court noted that the intrusion need not be physical and remarked that eavesdropping on bedroom conversations of a married couple was plainly a situation that would be offensive to any person of ordinary sensibilities. It was observed that recent social trends emphasize the requirement for protecting the innocent from such invasions of privacy. In the words of the New Hampshire Supreme Court:

> . . . If the Peeping Tom, the Big Ear and the electronic eavesdropper (whether ingenious or ingenuous) have a place in the hierarchy of social values, it ought not to be at the expense of a married couple minding their own business in the seclusion of their bedroom who have never asked for or by their conduct deserved a potential projection of their private conversations and actions to their landlord or to others.

RECOMMENDATIONS FOR LEGISLATION

It may be observed that in May of 1968 the Senate referred to the House the Omnibus Crime Control and Safe Streets Bill, which included recommendations to permit wiretapping and electronic eavesdropping by law enforcement officers under clearly specified conditions, which include the necessity for obtaining search warrants. The application of this measure would include the emergency application of these techniques without search warrants for periods no longer than forty-eight hours, after which time a search warrant must be procured. Included are provisions governing the length of the surveillance order and the length of renewal actions. It was passed by the House and signed into law by President Johnson in June, 1968, despite the President's previously stated opposition to the use of general eavesdropping and wiretapping in nonsecurity cases.[64] This promises, by preemption, to have significant effect upon the laws of the states. All other such similar bills that had been brought before Congress in the past had been ill-fated, the only regulation prior to the passage of this bill being Section 605 and Part 15 of the Federal Communications Act.

Westin[65] suggests four basic criteria to delimit the control of surveillance devices and processes. First, he states that rules must be adopted limiting those who are allowed to conduct the surveillance. He states that the history of police use of eavesdropping is sufficiently stained with misconduct throughout the nation that the use of physical surveillance devices in the states should be limited to district attorneys' offices and state attorney generals' offices and at the federal level to the Federal Bureau of Investigation and military investigation agencies. He feels that private investigators should be specifically forbidden to engage in physical surveillance with modern listening and watching devices and that owners of property which caters to the public should be forbidden to install and use secret surveillance devices, unless notices are prominently displayed that they are in use.

Secondly, Westin would detail regulations regarding the scope, duration and operations of the surveillance. The rule of scope for physical surveillance would determine the types of crimes for

which surveillance is permitted and the places that may be monitored. The rules of duration would determine the length of time that physical surveillance might be carried on, with recommendations for short, renewable periods. The rules of operation must specify the manner in which surveillance should be conducted--the type of monitoring equipment to be used and the methods of identifying and preserving the physical recordings.

Thirdly, Westin recommends that some general agency should be created to set standards for surveillance, supervise practices under the adopted rules, investigate compliance and hear complaints about misconduct. He holds that if law enforcement officials are involved, a system of judicial order must be used and that much more careful rules would have to be set for demonstrating the need to use physical surveillance than have been true under the warrant system.

The fourth step recommended by Westin is the adoption of rules governing the disclosure and use of the information obtained by physical surveillance. He recommends that its use in court, whether in criminal trials or in civil cases, should be strictly reserved for information gathered in full conformity with the controls set by the system. Further, he holds that the refusal to admit evidence obtained in violation of this strict control system is the simplest and most practical way of enforcing complicance with the rules. Regulations must be developed for each surveillance process to ensure that the information gained is employed only for the purpose for which it was originally sought, and that access is allowed only those who must screen it for that particular purpose. Penalties enforced against the unauthorized disclosure or use of these techniques would tend to ensure guarantee of this protection of privacy with relation to the maintenance and disposal of the system itself.

Westin identifies five major private forces[66] that play a significant role in establishing the insurance of privacy in a democratic society: moral consciousness, scientific countermeasures, intra-organizational rules and decisions, private agreements and professional ethical standards. He feels that there has already been significant activity to strengthen these norms of privacy in

each of the aforementioned areas, but that much more is required.

With regard to moral consciousness, he notes the norms of privacy can change, just as other American norms on sexual conduct, race relations and international participation have changed profoundly in the past decades. Popular works such as Vance Packard's *The Naked Society* and Myron Brenton's *The Privacy Invaders* serve to link the new technology of surveillance to questionable aspects of commercial, social and governmental inquisitiveness in post-World-War II America. The climate of public opinion, he notes, may also be ready to support effective action to safeguard privacy if such action can be intelligently framed and presented effectively to the people.

> Something significant has obviously happened when a President of the United States quotes Justice Brandeis and calls for protection of privacy in a State of the Union message.[67]

With regard to scientific countermeasures, in the past the attention of the scientific community has primarily been directed at the development of countermeasures for military and diplomatic privacy. No major effort has been initiated to develop systems for the protection of the average citizen's privacy in ordinary conversation, telephone communication and during the day-to-day activities of his private life. Westin feels that telephone scramblers and radio surveillance jamming devices, in addition to other scientific countermeasures, could be cheaply developed so that they would be easily available to the private citizen and within his financial reach.

Wtih regard to intra-organizational restraints, largely these are dependent upon ethical issues adopted by the agencies and their organizational leaders. In a sense, a formalized code of ethical conduct adopted by these agencies should be sufficient to influence a respect for the privacy of the citizen.

Since American society relies heavily on private agreements and bargaining between individuals and groups and organizations, Westin recommends that agreements be activated by a new concern to assert the interests of privacy more strongly. He calls upon all citizens to stimulate interest in their contractual relation-

ships with organizations and business concerns in the protection of their own privacy. He suggests that this might be accomplished through the initiation of civil suits for pecuniary damages.

The enforcement of professional ethical standards protecting the privacy of communications would accomplish a great deal, since many of the physical techniques exercised in the invasion of privacy are used by members of the professions. Mentioned are doctors, lawyers, accountants, journalists, sociologists, psychologists, political scientists, historians and anthropologists. Westin notes that in many of these professions the framework for regulation already exists, since these professions are subject to self-regulatory ethical codes or to governmental regulation applied through licensing of the profession. Both are internally adopted, and the externally imposed codes of conduct are designed to define standards for professional behavior and to serve as guidelines for borderline problems. He notes that the sanctions available for violations of ethical conduct may vary greatly in nature and effect, but that this disciplinary action quite often exerts an influence in professional life. Of special note is the lawyers' use of recording devices with clients, with other lawyers and in the employment of private investigators, which has been raised under the existing framework of the legal Canon of Ethics by the Special Committee on Science and Law of the Association of the Bar of the City of New York. It is felt that attention to this problem will probably increase within the professional societies, as the attention of the public is concentrated on these problems of ethics.

Westin poses a series of changes that seem indicated for regulation of physical surveillance. He notes that the problem that appears to need legislation most acutely is that of wiretapping, electronic eavesdropping and optical surveillance. It appears obvious that the Supreme Court feels that no more can be done with the ambiguous language of Section 605 of the Federal Communications Act and has eagerly sought Congressional clarification.

Since neither the New York statute nor the Illinois statute, dealing with electronic eavesdropping, has been widely accepted

in other states, it is apparent that most of the other states appear to be expecting Congress to take the initial steps in legislation.

Westin recommends that both federal and state statutes be enacted to control these physical surveillance devices and that a limited power be granted certain public agencies to conduct such electronic surveillance. He notes that there probably should be differences between the federal and the state laws because of the different governmental powers and responsibilities. State laws, operating under broad state police powers, would apply to all persons within the state's jurisdiction, in contrast with the federal statute, which in many instances would be applied only to federal officers. Common to these statutes would be four basic elements[68]: prohibitions against unreasonable surveillance by technological devices, exceptions for the legitimate private use of surveillance devices; a system of court-controlled use by law enforcement officials in limited instances and assorted remedies providing for private and public enforcement of the statutory limitations.

Westin advises that the federal statute on unreasonable physical surveillance by instruments should begin with the mention of three prohibitions, followed by a list of exceptions. He would first protect telephone communication, then the protective jurisdiction over radio frequencies and their use and the prohibition for any federal officer, or his agent, to use physical surveillance instruments to observe, overhear or record—without the subject's knowledge and consent—the location, conversation or activities of any person in a private place or engaging in a private conversation in a public place.

The second section of the proposed federal statute would be the exceptions dealing with the use of surveillance devices in certain limited instances. They would be allowed in cases where they were aids to impaired physical functions (for example, hearing aids) and certain situations where the consent for overhearing would be implied (such as with a marine band, citizens' band or ham radio conversations); applications of research, education and therapy conducted by federal employees when the individual has given specific or general consent to the experiment;

for the physical protection of private or government property from intrusion or to ensure personal safety of citizens, only when notice of surveillance is clearly posted for all to see; and to include the routine servicing of the communications devices by authorized operators or repairmen in a way that does not invade needlessly into private communications.

The third portion of the statute would allow a limited employment of physical surveillance by federal law officers. Here might be included a listing of crimes for which physical surveillance would be authorized and to provide punishments for the violation of these regulations. Westin recommends that congressional hearings be conducted on this topic to authorize surveillance in cases of this nature after allowing federal and state law enforcement agencies to present cases for allowing surveillance relating to a particular crime or area of investigation.

Westin's own feeling is that federal technological surveillance should be restricted to the Federal Bureau of Investigation and perhaps a few other law enforcement agencies, such as the Secret Service. In certain extremely serious cases and in intelligence and espionage work, he notes that CIA and military intelligence agencies probably would be exempted from the statute, when engaged in national security investigations. Provisions would have to be made in the statute for authority to use surveillance devices to be granted by application to a federal district judge in the district where the surveillance by instrument was to take place. This procedure would include provision for initiating the surveillance for very short periods and during emergency situations, when it is not possible to obtain written authorization from the attorney general. The statute should include a provision requiring an application be made for surveillance within twenty-four hours of its initiation. The surveillance order, when granted, would continue in effect for twenty days and could be renewed by the judge who granted it initially for additional twenty-day periods, upon the demonstration of a continued need. He recommends that surveillance of public telephones or public premises should be granted only for ten days, renewable for 10-day periods.

In this system it would be critical that all records obtained

during surveillance operation authorized under the statute would be turned over to the attorney general, registered and preserved, with destruction permitted only by court order. In a federal criminal trial the defendant would be entitled to have the Court inquire of the government whether surveillance by instrument had been used in the case against him. As a preliminary disclosure in all criminal trials, Westin notes that the law might require an affidavit by the government stating that surveillance by device had been used at any time during the investigation of the case against the defendant. If this were the case, the defendant might then challenge the sufficiency of the probable cause for issuing this surveillance order. It is noted that defense counsel would probably want to examine all recordings, pictures and notes taken during such authorized surveillance and it is recommended that the presiding judge at the criminal trial be permitted to examine the surveillance evidence first and remove material not relevant to the defendant, which might expose the privacy of others not related to the defendant's case.

In the fourth, and final, section of the federal statute would be provided remedies for violations. Westin feels that this may be the most crucial portion of the statute. He recommends that criminal sanctions be imposed against those violating the statute's policy and suggests that probably a one to three-year penalty would be appropriate. Further, evidence obtained directly by or as a fruit of such violation would be excluded from any proceedings in federal courts and that a strict antidisclosure provision be included.

It is recommended that the statute should go beyond these remedies and provide both injunctive relief and damage suits for those persons whose privacy has been unlawfully or unreasonably invaded.

With regard to state statutes, it is recommended that separate state statutes on unreasonable surveillance by instrument would be necessary. It is suggested that these statutes follow the format of the federal statute under the general police power of the state. However, the prohibitions would be directed against all individuals as well as state officers.

Westin recommends that electronic surveillance by state authorities should be restricted to district attorneys' and prosecutors' offices, since the record of police departments and the problems in spreading surveillance powers too widely are strongly persuasive grounds for centralizing this power in the hands of lawyer-staffed and more independent prosecutive offices.

The problem of determining which crimes could be investigated through the use of physical surveillance devices would require the same screening suggested for the proposed federal statute. He notes that it is essential that the list of authorized crimes not include moral offenses, political protest and freedom-of-association matters.

In line with the regulations for the federal statute, authorization for state use of these devices would be required from a state judge and the applications, supporting documents and surveillance orders would go to a central judicial authority. Annual reports of such surveillance activity would be required to be prepared by the chief magistrate as well as the state attorney general and be submitted to the state legislature.

Included also should be provisions for remedies. Westin feels that an additional provision that should be considered at the state level is the creation of an independent agency to coordinate the protection of privacy from unreasonable surveillance. He recommends that the agency be composed of members chosen by the governor, the chief judge of the state's highest court and president of the state senate, and he suggests that the agency be authorized to receive complaints and to conduct investigations into the employment of surveillance devices by the agencies of the various political subdivisions of the state. Subpoena power and the ability to make on-site inspections would be included in the duties of the agency, in addition to the requirement to make annual public reports of its findings and recommended legislative and administrative reforms.

Westin holds that as discussions of private and governmental remedies have shown, American society at this time appears set to realize the impact of science on privacy. Failure to do this, he suggests, leaves the foundations of our free society in peril.

It is recognized that this problem is not merely one faced in the United States. Although science and social development in this country have made us the first modern nation to undergo the crisis of surveillance technology, other nations of the West follow closely behind. He observes that

> . . . the setting—the marvels of microminiaturization and circuitry, chemical synthesis . . . is new. The choices are as old as man's history of the planet. Will the tools be used for man's liberation or his subjugation? In the density, complexity, and tight interrelation of twentieth century life, can we preserve the opportunities for privacy without which our whole system of civil liberties may become formalistic ritual? Science and privacy: together they constitute twin conditions of freedom in the twentieth century.

A beginning basis for Westin's recommendations appear to be contained in the surveillance provisions of the Omnibus Crime Control and Safe Streets Act.

In his book, *The Intruders,* Senator Edward V. Long (Dem.-Mo.)[69] has these suggestions for a solution to the problem of wiretapping:

> . . . all private wiretapping should be prohibited; both tapping and divulgence should be considered crimes; one party to a call should be permitted to have a third party listen in or record the call, provided any other party or parties to the call are given notice; and that law enforcement officers should be allowed to tap with the consent of one party to the conversation, under specified conditions. With such consent, they should be able to listen to or record a telephone conversation, provided they have obtained a court order. Here, the order could and should be limited to specific conversations and to conversations that constitute a crime or may reasonably be expected to be an integral part of a crime. The other requirements for obtaining a search warrant should also be met. This would provide law enforcement with an important tool in gambling, prostitution and narcotics investigations, without lessening the powers of the Fourth Amendment to protect privacy. This form of evidence should also be admissible in court. Where a person is a victim of a kidnapper or extortionist, or offered a bribe, law enforcement officers should be allowed, with the victim's consent, to monitor telephone calls placed to him by the criminal without court orders. However, an order should be obtained within 24

hours after the police receive notice of the crime. In this situation, again, the order could and should meet the requirements of the Fourth Amendment and the evidence should be admissible.

When neither party to the telephone call has consented, law enforcement officers should be prohibited from wiretapping. Both interception and divulgence thereof should be considered crimes.

In the court order situation here indicated, provision should be made, where a prosecution is brought, to notify the subject of the tap that his conversation has been seized. This should be done in adequate time before trial for him to challenge the order. In all cases, returns should be made to the issuing judge without delay to inform him of the action taken under authority of his order. In view of limited nature of the surveillance the court should not have difficulty in reviewing the results.

In national security cases, involving a clear danger, the President, as Commander-in-Chief, would have authority to order tapping, at least so long as the Olmstead decision remains in effect. Information so obtained would not be admissible in court. Should Olmstead be overruled at some future time, then the Constitution would require that national security taps be subject to the same restrictions as other law enforcement taps.

This recommended federal legislation should be made applicable to federal and state law enforcement officers and federal and state courts.

With relation to audio surveillance, because few legislative efforts have been made to regulate it, less evidence has been presented to support the need for its use in law enforcement. The possibility of court orders for bugging meeting the requirements of the Fourth Amendment seems to be limited; while wiretap picks up all conversation on a specific wire, the planted "bug" will pick up all conversation in one particular location. Individual conversations are not limited, as in a wiretap, although if they were, the conversation normally would only be evidence per se.

There is also a problem here of continuing seizure. It would appear that the Fourth Amendment precludes the use of all "bugs" where a physical intrusion would be made to accomplish the installation. At any rate, they are similar to the wiretap in that their employment is not in consonance with democratic ideals.

Senator Long observes that it is not possible for Congress alone to protect privacy against all electronic snoopers but suggests the following approach to the problem. The use of electronic devices by law enforcement officers and informants should be allowed with court orders if the government agent is a participant in the monitored conversation or has the consent of one party to the conversation. Requirements similar to those outlined for wiretap court orders should be imposed. This would necessitate both federal and state legislative action. Congress should specifically ban the use of radio devices by private citizens to monitor private conversations, and the separate states should likewise prohibit the use of wired "bugs" and recorders. An exception to this would be provided where all parties to the conversation consent to the monitoring and recording. He notes that the prohibition must be limited to private conversations or serious interference with radio and television coverage of public events would be effected. Also exempted would be private conversations accidentally and unavoidably heard under these and testing circumstances. Here again, both monitoring and divulgence should be considered crimes. He recommends that telephone companies should be barred from leasing lines to government agencies for wiretapping and bugging. The advertisement of audio surveillance devices should be prohibited. Since miniature transmitters and recorders certainly have legitimate uses, their advertisement for legitimate purposes is entirely proper; however, he feels that there is no reason to allow them to be promoted for private prying and snooping. Regulation of manufacturers and distributors of surveillance equipment should be initiated and the distribution of these devices should be regulated by a government agency. A final suggestion is the framing by Congress of a code of conduct for federal investigators. The code would set out the "do's" and "don'ts" in relations with, and treatment of, both suspects and third parties. The code would have to be drawn up with extreme care so as not to interfere unnecessarily with the investigator's initiative.[70] Senator Long maintains that with adequate education programs and supervision, it might not be necessary to employ such a statutory code, especially if provision were made for all

federal agency operations manuals to be reviewed by an independent authority. Civil law should not be neglected in its capacity to protect the right of privacy against the intrusions noted, according to Senator Long. It is recommended by him that each state survey its own civil law in these areas and that legislation should be enacted to establish a comprehensive and actionable right of privacy to include punitive damages for any abuse of these rights. Unfortunately, much of the impact of Senator Long's views, as well as public trust in the integrity of his guidance of his subcommittee investigating the "invasion of privacy" in this country, have suffered (and faltered) after the public disclosure that he had accepted $48,000 "for legal services" from convicted Teamsters' Union boss James Hoffa's attorney, Morris Shenker.[71] It would appear to some that Senator Long was paid to stage his entire subcommittee investigation to gain emotional support for an appeal to free another influential hoodlum.

In the words of the Special Committee on Science and Law of the Association of the Bar of the City of New York in a statement issued on November 15, 1965, "It . . . requires that our businessmen, our district attorneys, our journalists, our men of science—to mention only a few—be concerned with the human claim to privacy as well as their dominant respective concerns for the profitable enterprise, the enforcement of society's laws, the freedom of the press and the freedom of science. . . ."[72]

In June of 1968, Congress passed, and President Johnson signed into law the Omnibus Crime Control and Safe Streets Act containing the first federal permissive wiretap clause. Provision is made for court-ordered wiretaps in criminal cases for specified thirty-day periods, with a 48-hour "grace" period allowed for installation of initial taps before court approval is sought. Just how this legislative change will influence field operations in the administration of justice is difficult to predict, however the adoption of a system of internal controls assumes a new degree of importance.

Sections 2510 through 2520, Title 18 U.S.C., a substitute for Section 605, Title 14 U.S.C., deal with the regulation of the

interception of oral and wire communications in the United States, and provide penalties of up to $10,000 fine and/or five years imprisonment for violations thereof. Pertinent extracts are shown:

Section 2510—Definitions.
Section 2511—Prohibits the illegal interception, or the endeavor to illegally intercept, of any oral or wire communication, or of any disclosure thereof.
—Exempts therefrom a party to a communication who gives his permission to monitor.
Section 2512—Prohibits devices primarily useful in surreptitious interception of oral or wire communications (advertising, assembling, manufacturing, possessing, selling, sending through mails, or transporting through interstate or foreign commerce.)
Section 2513—Provides for seizure and forfeiture to the U.S., of prohibited devices.
Section 2514—Provides for granting immunity to witnesses.
Section 2515—Provides for proscription of evidence unlawfully gathered in violation of these sections, in federal or state courts.
Section 2520—Provides for civil remedy.

Several cases involving this law are now a matter of record. In *U.S. v. Kelly and McCann* (April 16, 1970), a conviction was obtained wherein defendants used a battery-operated FM transmitter on a telephone line. Each was sentenced to three years in prison. In *U.S. v. Novel* (June 15, 1971), defendant was convicted for unlawful possession of a voice-activated tape recorder concealed in a briefcase and a telephone tapping device.

Under this law, it may be noted, the only lawful surreptitious interception that may be done in criminal law enforcement is under competent court order. In the states not operating under a court order law, such as California for example, *all* such activity is unlawful. It would appear, then, that every California law enforcement agency possessing prohibited equipment or devices is now committing a federal felony by merely possessing the devices. Needless to add, every instance of unlawful usage of this equipment results in another violation.

It may be noted that the law exempts certain acts, and that it is possible to use some of these *techniques,* but under a different

section the *equipment* is made unlawful! Prohibited devices include, but are not limited to, the following: spike microphones, wristwatch, cufflink, tie clip and fountain pen microphones, infinity transmitters, all wiretapping equipment, and any subminiature disguised radio transmitters, in addition to sound recorders hidden in or disguised as something other than what they are.

In an effort to obtain convictions of attorneys and technicians dealing in unlawful interceptions, provision in the law is made for the granting of immunity from prosecution to cooperative defendants who will testify against those who gave them aid. Any attorney will recognize that the drafters of this section anticipated the prosecution of some sieve-like cases!

Permissive electronic surveillance statutes, as of May 1970, have been enacted by the following states: Arizona, Colorado, Florida, Georgia, Kansas, Massachusetts, Minnesota, Nebraska, New Jersey, New York, Rhode Island, South Dakota and Wisconsin. Such legislation was then pending in California, Louisiana, Michigan and Ohio. As might be expected, based upon a knowledge of the metastases of organized crime, this legislation is critically needed in California, Illinois, Pennsylvania and Ohio. In California, as of 1971, legislative efforts for permissive statutes were again defeated by the same political bloc.

In the final section of this work will be found a series of recommendations for the employment, by public agencies, of electronic audio surveillance devices in cases which appear to legally and morally justify their use. Some effective system of internal controls *must* be instituted to prevent such widespread examples of misuse as discussed. The rights of the people will be best served by such regulation and internal "policing" springing from within the ranks of their local police forces.

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Chapter 8

ADMINISTRATIVE CONTROL OF ELECTRONIC AUDIO SURVEILLANCE USAGE

UNDER THE PROVISIONS of the Fourth Amendment to the United States Constitution,[1] the citizen is guaranteed certain rights; of these, the right of privacy and the right of the citizen to be secure in his home against unreasonable search and seizure have been lately in the forefront of public discussion as the result of excesses by law enforcement and private agencies. Enforcement units are placed in the position of exerting maximum effort in the suppression of crime and the protection of life and property and, in so doing, being required to operate within the framework of a number of divergent laws.

For many years in the United States, the gathering of criminal evidence was seemingly conducted on a catch-as-catch-can basis, wherein the end sought (the protection of the public) was prosecuted on the basis that it justified almost any means employed.

During the past decade there have been many changes in laws and criminal justice procedures which directly affect the gathering of evidence by agencies of law enforcement, in effect sharply restricting them from practices theretofore employed. Some of the most drastic changes have been in the area of the control of the use of electronic surveillance devices including hidden microphones, audio amplifying systems and the monitoring of personal communications facilities. These changes have been necessitated by the almost unrestricted use of audio surveillance techniques and devices on the part of both government, corporate and private agents. It appeared that the ends sought justified

the use of almost any means. Thus, unlawful entry, trespass, burglary and conspiracy began to characterize the implementation of these techniques. Such unlawful practices have grown, cancer-like, to include shakedown and extortion on the part of certain police officials throughout the country.

It is difficult to document some of these examples of "blue coat" crime, because of the existence of self-protective codes operant in most police and law enforcement agencies. We are left, as a result, to examine newspaper accounts and Supreme Court decisions, where the true state of affairs is *sometimes* revealed.

NOTABLE ABUSES

Dash *et al.* relate the following cases of historical significance, of the questionable use of these techniques[2]:

In 1895, the New York City Police Department had an arrangement with the telephone company whereby they had access to wiretap the entire telephone system of the city.[3] That this was probable is supported by the limited number of subscribers and telephone company centers of the day.

In 1916, the mayor of New York City initiated a police tap of the telephones of five Catholic priests in an alleged charity fraud investigation, which surprised no one when it was dropped before any indictments were made.[4] Based on this case, a legislative inquiry was initiated which probed the unrestricted wiretapping activities of the New York City Police Department.

In 1917, a police captain of New York City tapped the wires of all the telephones serving a midtown Manhattan hotel.[5] This was done through an arrangement with a private detective for the purposes of a divorce investigation. The captain was disciplined by the imposition of a fine of five days pay.

In 1934 and 1935, according to William G. H. Finch, former Chief, Telephone Division, Federal Communications Division, a watchman tapped the telephone lines of the White House "for entertainment and recreation."[6] Complaints had been received from Congress and the White House regarding wiretapping, and

the drop wires were traced to a telephone company test building used by the watchman.

In 1940, Governor Vanderbilt of Rhode Island initiated the tapping of the telephones of Rhode Island's attorney general and the mayor of Pawtucket in an investigation of alleged election frauds.[7] A private New York wiretapper was paid over $10,000 for this "public service."

In 1945, it was discovered later, Lieutenant Joseph Shimon of the Metropolitan Police Department, Washington, D.C., had engaged in a substantial number of private wiretapping operations which included monitoring the lines of a United States senator and various commercial airline representatives.[8] These activities reached public view during a Senate committee investigation in 1951 and indicated that Shimon had been operating in this manner since the early 1940's.

In 1950, the Grand Jury of New York City exposed numerous occurrences of illegal wiretapping by most of the four hundred plainclothes members of the New York City Police Department, which resulted in bribery, graft and corruption in general. This resulted in the adoption of regulations by the police department of substantially the same recommendations made by the New York Grand Jury in December, 1950.[9] An extract of that recommendation follows:

> The loose, irregular and careless methods of intercepting telephonic communications employed by members of the police department prior to the appointment of the present Police Commissioner, are invidious and supply fertile grounds for the breeding of police bribery and corruption. We therefore respectfully suggest and recommend to the Police Commissioner of the City of New York that the necessary amendments to the rules and regulations of the Police Department be adopted to effect the following results in all cases of wiretapping:
>
> 1. All requests for wiretapping orders should be made to the Legal Bureau only by a captain or higher ranking officer in the division embracing the area where it is desired to tap wires.
> 2. An affidavit in support of a wiretapping order should recite all prior applications made for orders to tap the same telephone and the current status thereof.

3. That affiant should appear personally before the Legal Bureau and there swear to the truth of the statements contained in said affidavit.
4. Where the facts stated in such an affidavit are alleged upon information and belief, such affidavit should state the precise and detailed sources of such information and the grounds for the affiant's belief. The duration of the order permitting wiretapping in any instance should not exceed sixty days.
5. The original order of the judge or justice permitting said wiretapping should be delivered by the Legal Bureau to the officer at whose request the order was obtained and a receipt therefor duly obtained.
6. Upon receipt of the original order, the commanding officer should assign, in writing, to a specific police officer the duty of executing the particular order, and a copy of such assignment should be forwarded to the Legal Bureau. The police officer to whom such duty is assigned, shall file the original or copy of such order with the proper telephone company and a report thereof made by him to the commanding officer reasonably thereafter.
7. The police officer thus assigned to the duty of intercepting the telephone communications, should present a written report to his commanding officer, thereafter, stating the place where the necessary connections have been made and a copy in writing should be sent by the commanding officer to the Legal Bureau.
8. The police officer tapping said wires should submit daily written reports to his commanding officer and to no other person, of all conversations and telephone numbers intercepted by him.
9. All original notes or writings of communications intercepted or other matters relative to said wiretapping should be forwarded by the police officer at the end of each day to his commanding officer.
10. All paraphernalia and equipment, such as earphones, recorders and tape used by any police officer in tapping wires should be the property of, and turned over by him, to the Police Department.
11. At the end of each listening period, the recorder should be sealed and tape marked with the date and time of sealing and should be taken by the police officer to the division office where it should be kept safely. Any arrests which may result from said wiretapping should be reported in writing to the Office of the Chief Inspector and a copy of said report sent to the Legal Bureau. Unless duly authorized, no police officer

> engaged in wiretapping should disclose to any person other than his commanding officer, the results of said wiretapping or any matter incident thereto.
> 12. Upon the conclusion of the tapping of any telephone, all records and reports and writings concerning said tap should be kept together so that complete information shall be immediately available with respect to any telephonic interceptions.
> 13. All reports, recommendations or advice with respect to any wiretaps should be in writing.
> 14. To effectuate the intent and purpose of the foregoing recommendations, the police commissioner should provide for maintaining and preserving all proper records. . . .

In New Orleans, in 1954, the telephone of the chief investigator of the New Orleans Crime Commission was tapped by members of the New Orleans Police Department, during the crime commission's investigation of the links between organized crime and the police department.[10] This revelation should afford the reader some idea of the operation of "professional" police at that time in the New Orleans area.

A Massachusetts Legislative Crime Commission, in 1955 and 1956, found organized crime and gambling racketeering was rampant in Massachusetts, especially in Boston. This situation existed with the knowledge and protection of police officers. Personal interviews by the investigators of the Pennsylvania Bar Association Endowment with persons engaged in the organized gambling racket in Boston all corroborated the findings of the Massachusetts Crime Commission that police officers were on the payroll of the gamblers and provided protection from their own (police) activities. The racketeering influences had excellent contacts with telephone company employees and were not worried about police tapping of their telephones. Boston Police officially deny wiretapping, although statements made by the district attorney of Boston in August, 1957, at the Annual Meeting in San Francisco of the National Association of County and Prosecuting Attorneys threw discredit on the official word of the Boston Police Department.[11]

Probably the most celebrated police bugging case in California was the monitoring of conversations of Mickey Cohen, by mem-

bers of the Los Angeles Police Department throughout the period 1945 to 1949. Involved were charges of extortion and graft against members of the police department—some high-ranking officers resigning after a lieutenant and a sergeant were indicted by the Grand Jury of Los Angeles County. A Superior Court trial judge later dismissed charges against the lieutenant, and the sergeant's case was discharged when a witness later admitted lying.[12]

JUDICIAL INVESTIGATIONS

Police all over California have been quietly wiretapping and bugging for years and have been discomfited by previous free admissions, by Los Angeles Police, of electronic surveillance activity. Two cases initiated by Los Angeles Police, which later brought condemnation by the U.S. Supreme Court for violation of the provisions of the Fourth Amendment, were the *Irvine* and the *Cahan* cases.

Irvine was an alleged bookmaker operating in the Los Angeles area. In 1951, Los Angeles Police surreptitiously entered his home, using a passkey produced by a locksmith and planted a hidden microphone for the purpose of gaining evidence of his activity. Two further entries were made to re-position the microphone when the recordings were found to be unsatisfactory. Irvine was later arrested and tried. He was convicted and subsequently appealed, whereupon the case stood although the Supreme Court was extremely critical of the actions of the police.

Cahan, similarly, was an alleged bookmaker operating in the Los Angeles area and police made several surreptitious installations of microphones, resulting in the later arrest of Cahan and fifteen other persons with incidental raids and forcible entry—all without warrants. The California Supreme Court, based on the warnings of the United States Supreme Court in the *Irvine* case and a previous narcotic case (*Rochin*) struck down the Cahan conviction. This action focused the attention of California law enforcement officials squarely on the Los Angeles Police Department.[14]

In 1950, in San Francisco, the *Tarantino* case resulted in a seeming paradox wherein the Supreme Court affirmed an extortion conviction where law enforcement officers made unauthorized entry in a manner similar to the *Irvine* and *Cahan* cases. In the *Tarantino* case, however, the target of the extortion was the mayor.

Dash *et al.* cite a case in California where a murder suspect was held in city jail and a visit from his girlfiend was expected. A visiting room was wired, and the microphone left unconnected until the next day. A night janitor, unaware that the bug had been installed, permitted an attorney to interview another prisoner in the room. It seems that the lawyer became suspicious, searched the room (there was reason to believe that the lawyer was tipped-off concerning the bug) and found the microphone. The lawyer then went directly to the newspapers and complained about the bugging.

The chief of police at that time stated to the papers that there was no microphone in the room. Later, on learning that his homicide detail had so installed the microphone, he called the newspapers and asked them not to report the story, saying that such disclosure would eliminate police chances of overhearing possible incriminating evidence. The newspapers carried the story anyway, since monitoring a conversation between attorney and client while in custody of police is unlawful in California.[15]

In 1948, Russell Mason, a Los Angeles sound technician well-known to his former police clients, surreptitiously installed several wiretaps and microphones in various offices in the State Building in Los Angeles. This included portions of the attorney general's office—admittedly authorized by an assistant attorney general. Mason was arrested and charged with wiretapping, although convicted of a lesser included offiense—making an unauthorized connection to telephone lines. He was sentenced to thirty days in the county jail and the sentence was suspended, although a deputy attorney general advised the court that Mason's activity *had been authorized.* This occurrence gave some credence to the rumor that the attorney general, himself, initiated

the bugging of the State Building meeting rooms to be occupied by a special crime study commission which was in the process of investigating the attorney general's office![17, 18]

In the Chicago Police Department there existed a specialized detective intelligence unit of about forty officers, familiarly known as "Scotland Yard." It was reportedly abandoned in 1956 when a new mayor revealed that his opponent, the then incumbent mayor, used "Scotland Yard" to tap his telephone. For many years later the unit operated directly out of the police commissioner's office, at a time when he publicly maintained that the Chicago Police Department did not use wiretapping in its criminal investigations. There is reason to believe that telephone company personnel, utilized to assist in surveillance of racketeers' telephones, often sold the information to the racketeers themselves, thus defeating the surveillance system.[19, 20]

The Philadelphia Police Department had eleven units operating who, on occasion, employed electronic surveillance apparatus. Many of the officers assigned to these details possessed their own wiretapping and bugging equipment, as was the case with the New York City and Chicago Police Departments. "Businesses," termed ' tap-burning," developed when members of surveillance units tipped-off subjects of investigations that they were being bugged. A survey of the Philadelphia Police Department by the Police Commission designed to reveal that electronic surveillance equipment was personally owned by individual officers resulted in reports from eighty officers, although it was doubtful if all such officers responded to the survey.[21]

A Special Grand Jury investigation resulted in Philadelphia in 1950 when officers of the Philadelphia Police Department were charged with falsifying court orders in order to obtain records of toll calls from the telephone company.[22] This, it may be noted, was only one example of many "irregularities" encountered in the Philadelphia jurisdiction.

The Philadelphia District Attorney's Office was involved in 1957 in the release of wiretap transcripts relating to labor union affairs to the area newspapers. Another case in the same area resulted when wiretap transcripts were sold to news media during an investigation of the organized prostitution of juveniles.[23]

SENATE INVESTIGATIONS

On February 18, 1965, investigations were begun by the United States Senate's Subcommittee on Administrative Practice and Procedure, into alleged invasions of privacy of citizens by federal agencies.[24]

A primary target of the investigation was the United States Post Office Department, in addition to the United States Food and Drug Administration, and several other "nonsecurity agencies."

Senator Edward V. Long (Dem.-Mo.), Chairman of the Subcommittee, announced that agencies not concerned directly with security or law enforcement have purchased a considerable quantity of electronic surveillance equipment. Surveys were sent out to a number of departments. Of these, two refused specific information, and the answers of others seemed incomplete.[25]

Agencies purchasing and using this type of equipment included the General Services Administration, Federal Bureau of Investigation, Post Office Department, Food and Drug Administration, and the Alcohol and Tobacco Tax Unit, Internal Revenue Service, Intelligence Division, Inspection Service and Bureau of Narcotics of the Treasury Department.

Although a senior FBI representative refused to reveal to the Subcommittee *any* information regarding his agency's use of these methods, many agents and supervisors of the Internal Revenue Service were interviewed and made admissions of unlawful activities relative to the gathering of evidence and information in cases coming under their purview.

I.R.S. Commissioner Sheldon Cohen, who proved a reluctant and (at times) a devious witness, admitted that his Pittsburgh agents unlawfully entered the private offices of a Pittsburgh area attorney and planted a hidden radio transmitter because of the attorney's suspected criminal activities; that they installed at least two unlawful telephone wiretaps; and that other Service agents engaged in numerous unlawful entries and established unlawful wiretaps in other sections of the country.

Testimony also revealed that the I.R.S. had installed electronic

audio surveillance devices and two-way surveillance mirrors in their "conference" rooms in at least the following cities: Alexandria, Baltimore, Brooklyn, Columbia, Detroit, New York and Pittsburgh.

A technique employed by them was to hold a conference between a taxpayer and his attorney or accountant and several I.R.S. agents in one of the "bugged" rooms, to fire a barrage of questions at the taxpayer, then to leave the room while the taxpayer consulted with his legal or financial advisor. The agents, of course, would monitor the entire "private" and (sometimes) "privileged" conversation. In many cases when the attorney for the taxpayer found out what had taken place and raised an outcry, he found that an investigation was begun on *his* affairs.

The testimony is replete with examples of Intelligence Division supervisors and Regional Coordinators denying that they sent out agents to wiretap, to break and enter offices and homes and to plant listening devices therein. Some of them even denied knowing that lockpicking and "bugging" were taught in the Treasury's Technical Aids School. Other agents and supervisors related that this was common knowledge in the Service.[26] Credibility gap or unvarnished lying—little wonder that many citizens are beginning to distrust the statements made by their own governments' representatives.

The objectives of the Subcommittee were to learn if the equipment was being used and, if so, for what purposes. They were also interested in just who utilized the equipment, and under what *internal controls* the devices were employed.

During the Hearings before the Subcommittee on Administrative Practice and Procedure of the Committee on the Judiciary, United States Senate, 89th Congress, July 13th through August 9th, 1965, Internal Revenue Service Commissioner Sheldon S. Cohen submitted a "complete list" of electronic investigation equipment owned by the Intelligence Division of his Service prior to January, 1961. This list consisted of five "intelligence kits," ten miniature tape recorders with shoulder holsters, one briefcase tape recorder, five microphones and one 60-power spotting scope.[27] He maintained that this equipment

was the only electronic technical aids used by the Intelligence Division to serve more than 1,800 enforcement agents spread throughout the United States.

During the same hearings Cresson O. Davis, chief of the same Intelligence Division, admitted to the procurement and use of thirty-three automatic dial telephone impulse-registers (pen registers) through 1962 and 1963.[28]

These hearings dealt with investigation of invasions of privacy by government investigative agencies--the Internal Revenue Service, in particular. Widespread wiretapping and bugging were admitted by all agents subpoenaed, although supervisorial personnel were aware that U. S. Treasury regulations have banned the use of wiretapping continuously since 1938.

In October, 1966, Mr. George H. Gage, Vice President, Telephone Operations Staff, General Telephone and Electronics Corp., rendered a report to the Long Subcommittee regarding operations of the General Telephone Company of California (the largest telephone operating company in the General system). In this report Mr. Gage mentioned that the company found only eighteen wiretaps on their subscribers' lines during the period 1962 through 1965.[29]

On the other hand, the New York City Police Department's Central Investigation Bureau in 1957 reported possessing and using seventy-seven automatic dial telephone impulse-registers (pen registers) of which no more than twelve were ever idle in any one day. It would appear then that sixty-five pen registers were in use daily.[30]

In New York City, during the period 1942 through 1954, the Office of the District Attorney, New York County, reported the number of wiretap orders as 916, an average per year of 70.5.[31]

In New York State, for the period 1950 through 1954, wiretap orders reported in thirty-two (out of sixty-one reporting) counties totaled 2,394, with 2,682 telephone numbers being tapped by court order.[32]

Subcommittee interest centered on a course in the use of electronic security equipment given in September, 1964, by the Fargo Company of San Francisco, a manufacturer of police

equipment. This course lasted for five days, cost $140 and caused a student to comment, "What I picked up in that school will keep me from ever pounding a beat." Covered in the instruction, attended by approximately 150 various government agents, were courses in lockpicking, wiretapping and audio and visual surveillance.[33] Besides familiarizing students with various technical devices, a basic *raison d'etre* appeared to be for the Fargo Company to peddle its own products, according to several students in attendance.[34]

This writer conducted a confidential survey of ten central and two statewide California law enforcement agencies employing electronic audio surveillance devices, which revealed that not one agency had in existence (to the knowledge of the informants) a written policy or general order regulating the use of this equipment. In addition, the decision to employ such techniques and devices rested solely in the hands of lower-level functioning personnel in all but one case.[35]

It seems reasonable, in light of historic developments and recent civil rights movements and court decisions, for the informed, capable police executive to concern himself directly with his department's use and control of these electronic methods of investigation. Additionally, of primary concern is the police executive's protection of the civil rights of the citizen, his agency's future and quite likely his own personal career, which may hinge on his initiation of a program of supervised administrative controls.

RECOMMENDATIONS

There appear to be two areas for consideration in a program of this nature. First, in consonance with standard executive practice, is the establishment of a written policy of the department's official aims with regard to electronic surveillance, implemented as time progresses by specific general and special orders and provisions for disciplinary action should individuals be in violation thereof. Second, a system of physical inventory, custody and control must be initiated and regulated by the chief executive. Incorporated in this system must be a reporting method whereby

responsible supervisory officers certify as to the authorized employment of this equipment in concord with the official policies and regulations remarked above. Needless to mention, regular unscheduled inspection must be a part of the procedure.

While it is recognized that professional enthusiasm may generate an extracurricular interest in this equipment, it is a reasonable policy to prohibit the possession by individual employees of any of these devices except when ordered by competent authority. Recent past history, as outlined earlier, supports the idea that uncontrolled, unrestricted employment of these techniques by officers with unlimited access to the equipment can result in unhealthy, if not downright crooked, practices. After all, we do not permit individual law enforcement employees to privately possess machine guns, silenced weapons, narcotic or dangerous drugs, counterfeit money or other restricted items. On the other hand, research, experimentation, and training may be enhanced by supervised, controlled training and research programs, as should be common in the daily functioning of the agency.

A persistent warning, evidenced by court decisions and an advanced public awareness, has been sounding for the benefit of law enforcement for the past decade, and law enforcement agencies, who must be alert for such signs of public intolerance, apparently have given little thought to the regulation of their own activities. It does not require the wisdom of a Delphic oracle to prophesy that if controls are not generated from within law enforcement organizations, they most surely will be applied from without—most likely accompanied by violent public reaction and resultant further suspicion and distrust by the judiciary. In such cases the police themselves may be creating the best argument for the creation of civilian police review boards.

ADMINISTRATIVE CONTROLS

Below are shown suggested sample orders and control devices which may be considered for adoption by using public agencies:

SAMPLE POLICY STATEMENT

Because this agency is charged with the protection of the rights of individuals, in addition to the protection of life and property and the suppression of crime, it is the policy of this department to employ only investigative procedures or techniques which conform to the various laws of the land. Departmental techniques of telephone line monitoring and use of hidden microphones and electronic surveillance devices must be in accordance with the provisions of state and Federal law and regulation and be employed only in accordance with this department's General Order ———. In permissible cases, use of these techniques will be restricted to investigations of crimes of a serious nature, such as treason, murder, felonious assaults, robbery, burglary, conspiracies and the corruption of public officials. In all other cases the use of these techniques is prohibited.

Included below is a sample of a recommended general order which might be employed in an agency having no adequate control system in existence:

SAMPLE GENERAL ORDER———

1. All requests for electronic surveillance orders will be made to the (*Chief's office or designated official*) by a captain or higher-ranking officer in the division concerned in the investigation.
2. Requests must detail the specific source of information leading to the desire for technical surveillance and state the grounds for the opinion of the officer so requesting.
3. When the commander receives written orders to proceed with the technical surveillance, he shall issue written orders for a particular employee to execute said technique of investigation.
4. The employee so ordered must report in writing to his commander immediately upon initiating the technical surveillance and furnish written reports daily only to his commander of the specific results of his surveillance.
5. The employee will daily turn-in to his commander all original notes and copies thereof, physical recordings and other matters thereto related.
6. Equipment and related items used by an employee in conducting any technical surveillance shall be the property of the department, possessed by him only on written order and turned-in to the equipment control section immediately upon completion of the assignment. Such equipment will be inventoried daily

and its proper disposition shall be certified to by the unit commander in writing.

7. Any physical records made as the result of such technical surveillance will be sealed by the employee and marked with the date and time of the surveillance, the subject and his own initials and stored securely in consonance with departmental order.
8. The employee engaged in the technical surveillance is hereby forbidden to disclose to any person, in any manner, the results, or partial results, of his surveillance, unless ordered so to do by a competent court, or authorized by a designated commander.
9. Any arrests or consequential leads gained as the result of the technical surveillance shall be reported in writing to the chief administrator by the responsible commander, and this report, along with other allied materials, shall be stored with the case file.
10. Violation of any portion of this order may be cause for summary dismissal; no disciplinary action taken under this paragraph shall be a bar to subsequent criminal or civil action.

SUMMARY

This chapter on administrative control of electronic audio surveillance devices has detailed some notable past examples of failure in the exercise of administrative controls by law enforcement executives. Included were examples of maladministration, inefficiency and corruption, to include unlawful entry, trespass, burglary, conspiracy and extortion.

The historical presentation of examples of degrading, and sometimes unlawful, police practices is followed by an examination of the inquiries of the judiciary into some of the more notorious abuses. Senate interest has been aroused and was reflected by the investigation of the Long Subcommittee in 1965.

Following these sections was included a series of recommendations for enabling adequate internal agency control of these sensitive practices. Incorporated here was a sample model for police and regulatory control of these surveillance methods and devices by the using law enforcement agency. Also included was a suggested policy statement and general order that might be adopted for agency use by concerned professional executive officers.

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4. *Supra,* note 2, p. 26.
5. *Supra,* note 2, p. 27.
6. *Supra,* note 2, p. 29.
7. Hearings on Sen. Res. 224 Before a Subcommittee of the Senate Committee on Interstate Commerce, 76th Congress, 3d Sess., Pt. 2, at 217-238 (1940).
8. Hearings Before the Subcommittee to Investigate Wiretapping in the District of Columbia of the Senate Committee on the District of Columbia, 81st Congress, 2d Sess., at 50-60 (1950).
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10. *Supra,* note 2, p. 153.
11. *Supra,* note 2, p. 151.
12. *Supra,* note 2, p. 175.
13. *Irvine v. People of California,* 347 U. S. 128 (1953).
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15. *People v. Tarantino,* 45 Cal. 2d 590 (1955).
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18. Personal interview: Russell Mason.
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27. *Supra,* note 26, p. 1153.
28. *Supra,* note 26, p. 1235.
29. *Supra,* note 26, p. 2697.
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31. *Supra,* note 30.
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35. Interviews: Confidential sources, by the writer, based on ten central California law enforcement agencies and two statewide California law enforcement groups, all employing electronic audio surveillance devices.

Chapter 9

ETHICAL CONSIDERATIONS

STATEMENT OF THE PROBLEM

THE PROBLEM OF ethical considerations dealing with the overhearing of the conversations of others is complicated at best. Involved are such questions as whether in the present state of technology, it is technically feasible for actual privacy to exist in a transaction between one person and another. Whether such transactions may deal strictly with a relationship between the persons involved or whether some facet of the transaction impinges upon the security of the society of which they are a part is another question to be examined. Is a society merely a collection of independent individuals or is it an entity unto itself, independent of the individuals composing it? An individual, placed in a society, probably has little personal impact upon that society, and when that individual is removed from that society, it may be observed that the society continues to function without noticeable change.

It is the acts of the individual which are actionable, rather than his words, in past legal considerations, although a determination of the *mens rea* is often decided on evidence of the actions *and words* of an individual, where they bear some interrelationship. In a democratic society the individual is guaranteed some basic rights as part of his participation in that society. These rights include a right to privacy and, according to the United States Constitution, the right to be secure against unreasonable search and seizure. From an ethical standpoint, where might the rights of the individual begin to falter in opposition to the right of a society to be secure in itself? When the words or actions of an individual threaten the security of the cooperative society,

it would seem that society should have the right to protect itself from those threats. Science places before us the capability for increased efficiency in the observation of man's actions and for the observation of his verbal utterances. Since both may be observed by other persons, it would follow that either or both observations might be used by society to protect itself. In certain circumstances this situation has been recognized by the courts as valid.

When two persons stand on a street corner conversing about an illegal act and in the process, are overheard by a third person, that third person may testify as to the conversation he has overheard. When an individual engages in a protected or confidential communication with certain classes of persons, he is guaranteed the protection of the confidentiality of that discussion. Should, however, a third party overhear such a discussion the confidentiality is dissolved, at least insofar as the third person is concerned.

The problem is similar when the third person passes in close proximity to where the conversation is being held. Generally speaking, if he is able to hear the conversation, he is able to testify to it. Related problems of identity, of course, may arise. When the conversation takes place within a "protected" location, that is, his "castle," it matters not if the windows are open and the sound waves generated are more easily dispersed to the atmosphere. If the walls of the house vibrate in consonance with the verbal activity generated within, a passerby might logically overhear what is transpiring within. When the conversation takes place over a closed-circuit, such as a telephone or telegraph wire, it may be reasonably expected by the parties thereto that it is a private conversation. On the other hand, any conversation carried on over a wire circuit has the capability of generating electromagnetic waves, in the vicinity of the wires, that might be expected to oscillate to infinity in the atmosphere.

Where the actions of a person or persons might be indistinct to the unaided eye of a third person, these actions may be made quite clear to the third person's eye by the use of a telescope or other form of lens system, such as a television transmitter. Cases

of this nature have proved to be outside the "protected" realm.

Science has made available certain instruments to aid as extensions of the senses in perceiving *what exists* but is ordinarily not detectable. Sound wave vibrations exist and are detectable by the unaided ear, up to a point. Through the application of sensitive electromechanical vibration detectors these vibrations may be heard. They are, of course, already present to a diminishing degree in the atmosphere. The same situation exists with the electromagnetic radiations emanating from a pair of wires in an electrical circuit or in the field of radio-frequency oscillations thrown free into the atmosphere to impinge upon the senses of any so equipped to detect them. The only tangible difference here is one of difference in the physical frequency of the vibrations.

The ear, operating as a detector, feeds these perceived signals to the brain where they are filtered, identified, considered, evaluated and stored. What we are faced with in a consideration of the use of electronic audio surveillance methods is the use of physical devices as extensions of the human senses to learn what is (already) transpiring in the atmosphere around us.

What difference can it make whether the third person overhears two others talking through an open window or whether he overhears the same conversation carried outside the house by a physical vibration of the walls or windows? Is the situation changed to any degree when the third person employs a sensitive microphone to help in converting these existing vibrations into audible sound waves? It makes little difference should the vibration detector be placed *on* the wall of the house or some distance away. The only difference is one of technology, since the effect is the same. When coherent light waves are reflected from a vibrating surface no contact, as ordinarily understood, exists; yet upon this principle the laser demodulator is enabled to operate.

In some areas, laws have been passed which prohibit the monitoring of any conversation between parties without the consent of *all* parties to the conversation. This thinking, it may be presumed, fails to take into consideration the impinging on

the atmosphere of these conversations. The conversations then become actions since they result in a physical change (expansion and rarification) in the atmosphere. There is nothing in the law which deigns to make it a crime for one of the parties to that conversation to repeat it to someone else or to testify about it later in court.

Someday, in the not-too-distant future, the possibility exists that we will be able to "read" brain wave emanations, wherein the requirement for speech would not even exist. In the past, in the eyes of the law, it has been necessary for the prospective victim of a crime *mala in se* to wait for some visible sign of action by the perpetrator that would signal his intention to carry out the crime. Were it possible to perceive brain wave emanations and to correctly interpret them, the victim would have an added opportunity to defend himself against the intended action. This "thought-wave" interpretation may be startling to some and further perpetuate fears of the "Big Brother is Watching You" (apologies to George Orwell) type of behavior. Based on the development of technology, it may not even be possible to make a determination of whether or not one wants to engage in this activity. It may even become a *necessity* to maintain one's homeostasis. The law, of course, has evidenced no progressive thinking along this avenue, much in the way that it has failed to take into consideration the physical measures of today's reality.

With regard to telephone line observation, in some areas it is considered by the courts to be permissible to monitor by induction, while direct connection with the line is considered unlawful. There is little physical difference here, and the act of connection becomes *mala prohibita.* In some areas the mechanical or magnetic recording of such conversations is unlawful, even for a co-participant in the conversation. It is permissible, of course, for the co-participant to make notes of the conversation or even to have a stenographer listen in on the conversation in order to preserve it. In these cases it would not be necessary to advise the other party to the conversation that note was being made of the conversation. Should, however, a magnetic recording be made of the conversation the other party thereto must be made aware of this fact.

With regard to the fidelity of the account of the conversation, the difference between a person's recollection of the conversation and a verbatim transcription of that conversation may be noted. Provided that the recording was skilfully made and represents a recognizable transcription of the conversation, it may be valuable to corroborate the interchange. Strictly speaking, the recording may easily be recognized as representing a form of physical "best evidence." Depending upon a person's mental set, his perception of the world around him, his physical condition and the degree to which communication is functional between himself and the other party to the conversation will an understanding about that conversation be reached. It is quite possible, of course, that both parties to a conversation might each fail to understand about what the other was talking and for both to believe that he did so understand. A verbatim electrical recording would, at least, make a permanent record of just what expressed verbal transaction did, in fact, take place.

DEFINITIONS

A narrow definition of crime is the legal conception—human behavior punishable under the law. It is, of course, much more than that. If, indeed, it were that simple then there would be little difficulty in identifying the limits of the field of criminology. There must be a differentiation of crimes per se and violations of technical provisions of the governmental administration. These acts, which are different from violations of the norms for the protection of the fundamental values of society, are not considered *mala prohibita.* Mannheim, in his work *Comparative Criminology,* states that ". . . no form of human behavior which is not antisocial should ever be treated as crime. . . ." He notes, however, that there are many types of antisocial behavior which are not and many others which should not be crimes.

By society, as herein considered, is meant the body of the population as a whole, the collection—the sum total of the people. It is a collection of individuals, but at the same time it is more than just this collection. Society is over and above the collection of individuals comprising its body. For society to be able to thus

function for the welfare of each of its members in a collective, protective state, this view must be adopted.

The individual, as we see him, is a unique person bearing certain rights and responsibilities and making up the bulwark of society. He gains certain of these rights from his association in his society and, in turn, accepts some limitations on his own freedom from such societal association.

The laws laid down by society may prohibit behavior which is illegal *and* immoral (*mala in se*) and that which is only unlawful and not immoral (*mala prohibita*). Other behavior possible may be immoral, but not unlawful. Since immoral behavior is defined by the mores of society, it may be seen that some changing or blending may periodically take place. Thus, acts which are both immoral and illegal during one period may be only illegal in another period, as the mores shift and blend with the passage of time and consequence.

The laws of nature, as we perceive them, may be regarded as static, and unchanging—therefore removed from the definition of man-made laws which are subject to the demands of society and (at times) the caprice of men.

The act of monitoring the conversations of others, *with no other consideration,* is essentially a neutral act. It is not, of itself, an evil act. The act may be tempered or flavored by the circumstances under which it is done or the uses to which it is put. The common-law crime of eavesdropping included the requirement of "publishing" the fruits of the listening to the disadvantage of the victim. Mere listening alone was never recognized as illegal, nor was it *necessarily* considered immoral; this, of course, was dependent on the mores of the society.

CONSIDERATIONS

The ethics of our social and political life is a mixture of various levels of social group ethics. It has developed that nations have generated through the fusions of states and the blending of social groups. The ethical rules of ancient times, including the laws which perpetuate the moral codes of the Romans, of the Church and of feudalism, have resulted in gross inconsistencies

in ethical systems. Should one attempt to follow all the moral rules in a large society, he will find himself frustrated by extensive ethical conflicts. Philosophy cannot answer these questions, nor can the methods of science. Science is often able to identify what *is*, but is not able to deal with what should be. What should be is often empirically determined by the norms of the society's mores.

Electronic audio surveillance, as an act, is indifferent in and of itself. It would follow then that the circumstances of its use would determine its morality. When such techniques are used for the good of the society against the interests of an individual who is attempting to harm that society, the act achieves a "good" morality. If it is used to protect an individual, a member of society, it is then a benefit to both the individual and, consequently, to the society and again achieves a moral "goodness."

To achieve a beneficial status, a moral act must have intrinsic goodness, achieve an extrinsic goodness or at least must counterbalance any evil involved by the "weight" of its projected goodness.

Where audio surveillance is used against the good of society or against the interests of an individual, a member of society, it then becomes an evil act. An example of this might be the case where it is employed in the blackmail or extortion of an individual.

There are cases where it may be used against an individual, a member of society, for a purpose wherein the gain to society is outweighed by the nature of the act against one of its members.

Decision must here be made as to the ethics of the situation, depending upon the propensity for good that the action bears for society as a whole, as weighted against its evil effects.

Supreme Court and Executive decisions that these techniques should only be used in "national security" cases appear to fall short of the aim of protecting society against the depredations of other types of criminals.

Just as each individual is possessed of certain rights, so also is society itself possessed of the right of "self-preservation." Each citizen, who moves as a part of society, must give up to that society certain of his privileges of freedom and liberty. If there were no laws there would be no crime. If all members of a society

maintained complete freedom of movement, speech and action, the society would be on dangerous ground. If all members of that society *exercised* those prerogatives of liberty, there could be only chaos.

For each benefit a man gains from his association in a society, he must surrender certain of his liberties. Here we are concerned particularly with his right to privacy. Privacy and the right to freely pursue his own ends are hallmarks of his heritage in a free society. The rights of the individual, it is said, must remain inviolate. The question with which we are here concerned is this: if the individual's right to privacy should remain inviolate, subject to due process of the law, then what of the rights of all the other members of the collective society? Must society lose its inherent right to self-protection against those who seek its downfall because of overzealous guarding of individual rights?

With regard to the individual's privacy, how far must the physical borders extend—to the secret conversation he conducts on a street corner or in a public park; to the borders of the walls of his office, of his domicile, of his bedroom; or only to the borders of his brain case?

Scientists recognize that as the technology forges ahead in rapid strides, it is society that must, and will, adapt to the changes created by these technological advances. Present capability of state-of-the-art surveillance techniques include the use of light waves to demodulate vibrating surfaces from vast distances. Future developments, as has been remarked previously, may include the capability of interpreting brain wave patterns. Perhaps it is not fair to face a society, unprepared to cope with the technology of today, with the possibilities of the near future.

It is the thesis of this author that the citizen of today must be made aware of these technological changes which affect his privacy and that he should conduct his daily affairs with the realization that these techniques are being utilized today and that more sophisticated methods are near at hand.

The courts must realize that in order to protect society against sophisticated and organized criminals, audio surveillance orders

(search warrants) must be issued upon sworn application therefore by professionals who have knowledge of the indications of crime and of the suspect's participation in such unlawful activities. All of the ordinary safeguards attending the issuance of warrants should be adopted to provide for temporary surveillance when it is not possible to procure a court order on short notice.

The gravity of the crime must be considered by the investigating officers and, in turn, by the court. The crime must be of such a nature as to be a serious threat to the society should it be allowed to go unabated. These techniques should not be used on trivial offenses, nor on the purely regulatory violations.

As an instrument for the furtherance of justice electronic audio surveillance may be a two-edged sword and, if not adequately controlled, may be perverted into an instrument of oppression. The use of electronic audio surveillance must be equated against those benefits to society which might accrue from its employment. If there is a clear advantage for society to gain and to protect itself these methods should be available for tightly controlled use —if no such clear societal advantage is evident, then the act becomes immoral and must be proscribed.

The purpose of this study has been to present a working picture of the methods used in electronic audio surveillance, up to this time, and to study the system of laws set up to deal with the problem as it has developed. Included, also, has been a section outlining appropriate countermeasures in order that security against the use of these methods might be enhanced. In addition, a set of recommended administrative control guidelines were included in an attempt to demonstrate the possibility of a "self-policing" concept in professional law enforcement.

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SUMMARY AND CONCLUSIONS

IT HAS BEEN THE intent of the writer to present herein an orientation to the world of electronic audio surveillance and to outline in detail some widespread examples of the uses and abuses of these techniques concurrent with their development.

In Part A, "Systems," the basic principles of electronics have been examined—the operation of microphones, audio amplifiers, magnetic sound recorders, telephone systems and radio transmitters and receivers.

Based on this outline of the physical basis for the use of instruments in the surveillance of man's criminal activities, Part B, "Operations," presented the specific utilization of electronic audio surveillance techniques in investigative operations. Part B also presented, in contrast, a chapter on electronic audio surveillance countermeasures—consisting of defenses against the use of these techniques.

Part C, "Evaluations," as the closing and perhaps the most important section, treated the legal and regulatory background of electronic audio surveillance from the standpoint of the Fourth Amendment to the Constitution of the United States and the laws of the various states. Considered, also, was a series of recommendations and considerations, dealing with the safeguarding of rights to privacy presented by the distinguished jurist, Professor A. Westin of Columbia University.

Next was examined some notable examples of failure in the exercise of administrative controls by law enforcement executives in this area of the employment of electronic audio surveillance techniques. In the latter part of this chapter was presented a sample model for policy and regulatory control of these surveillance methods and devices by the using law enforcement agency. Included therein was a suggested policy statement and general

order that might be adapted for agency use by concerned executive officers.

In the final chapter was developed some considerations of ethical factors that bear undeniably on society's employment of surreptitious audio surveillance of man's activities as a member of that society, as an integral part thereof; some positions were taken with regard to the use of these techniques to protect society, in view of individual rights. Some discussion of selection criteria was also presented in support of these positions.

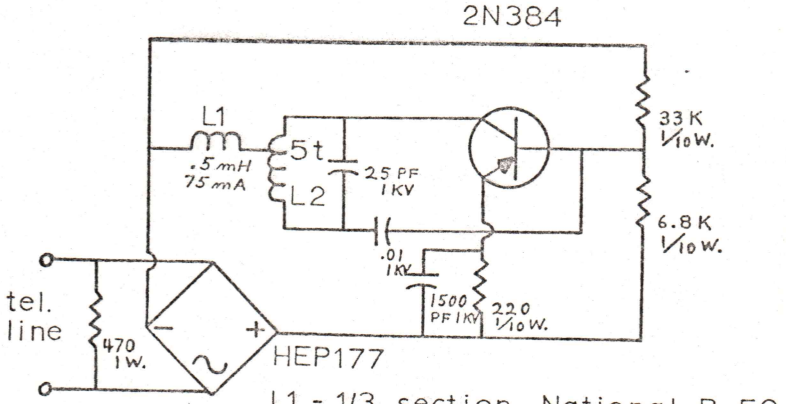
The proper employment of electronic audio surveillance devices and techniques, applied in conformity with current law and regulation, has much to offer as an effective tool in aid of the administration of criminal justice. These methods have proven of inestimable value in investigations of espionage and subversion and of major crimes, such as murder, kidnapping, robbery, burglary, grand theft, organized vice and criminal conspiracies. It has furnished vast amounts of valuable information regarding the extent of the network of organized crime syndicates in the United States and their international connections.

Properly used, this tool will continue to be of usefulness in serving the ends of justice; on the other hand, if it is characterized more by its misuse and lack of controls, the beneficient aspects of electronic audio surveillance may soon be denied completely to law enforcement.

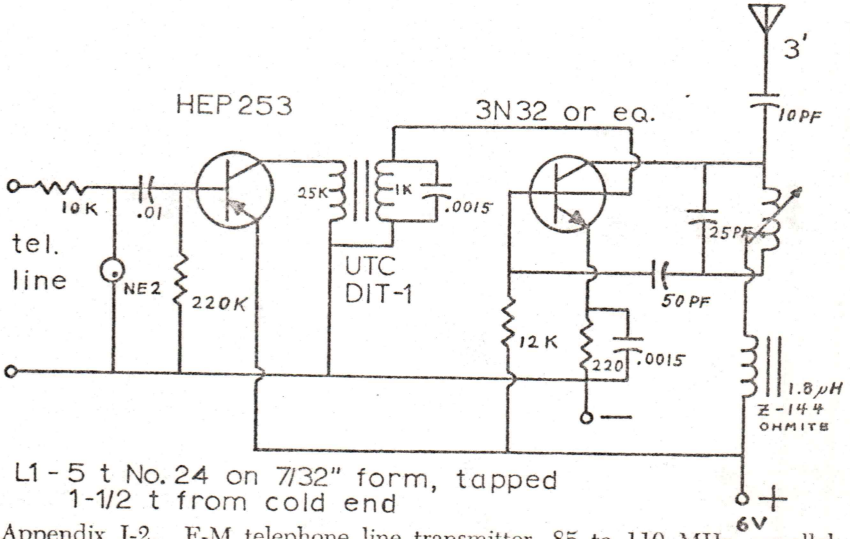
In conclusion, it is recognized that the foregoing suggestions with regard to policy and general orders may not be THE ANSWER to problems arising in the future with regard to this phase of investigation, but they are offered in the spirit that there must be a beginning, lest law enforcement lose completely another potentially powerful weapon in the struggle against organized crime.

Appendix I

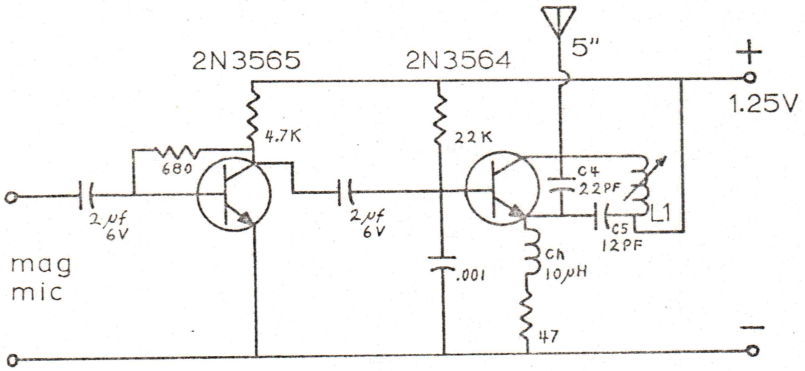
OTHER USEFUL ELECTRONIC AUDIO SURVEILLANCE CIRCUITS



Appendix I-1. F-M telephone line transmitter, 40 MHz, series-connected.



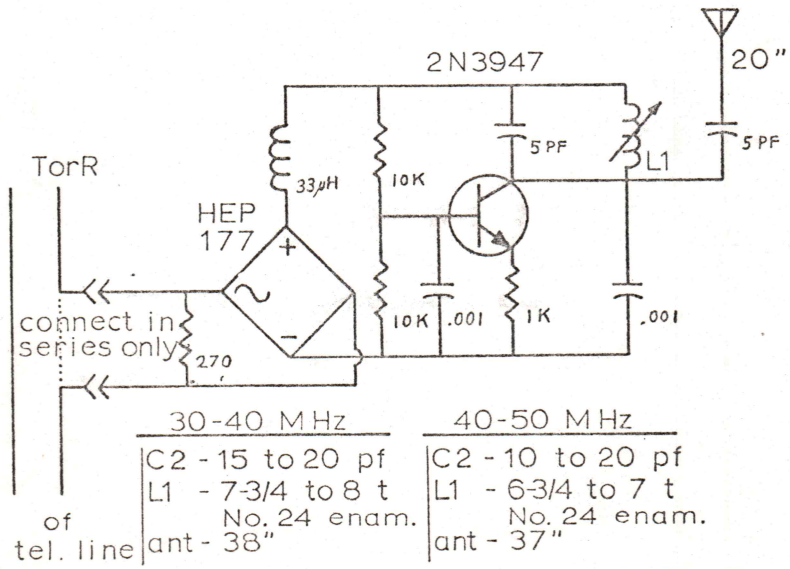
Appendix I-2. F-M telephone line transmitter, 85 to 110 MHz, parallel-connected.



Ch - Miller 9310 - 36
L1 - 6 to 7 t No. 22 on Miller 4300 - 5

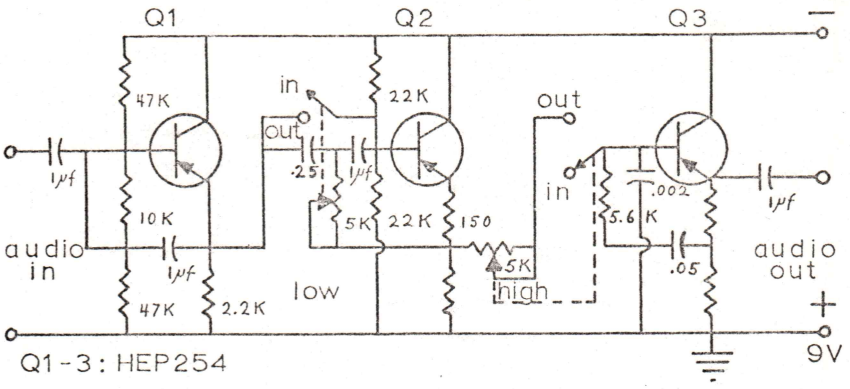
40-50 MHz
C4 - 40 pf
C5 - 22 pf
L1 - 12 t No. 22 enam.
ant - 9"

Appendix I-3. Subminiature F-M transmitter, 40 to 50 MHz or 85 to 110 MHz; encapsulated size, 1" x 1.25" x .25".

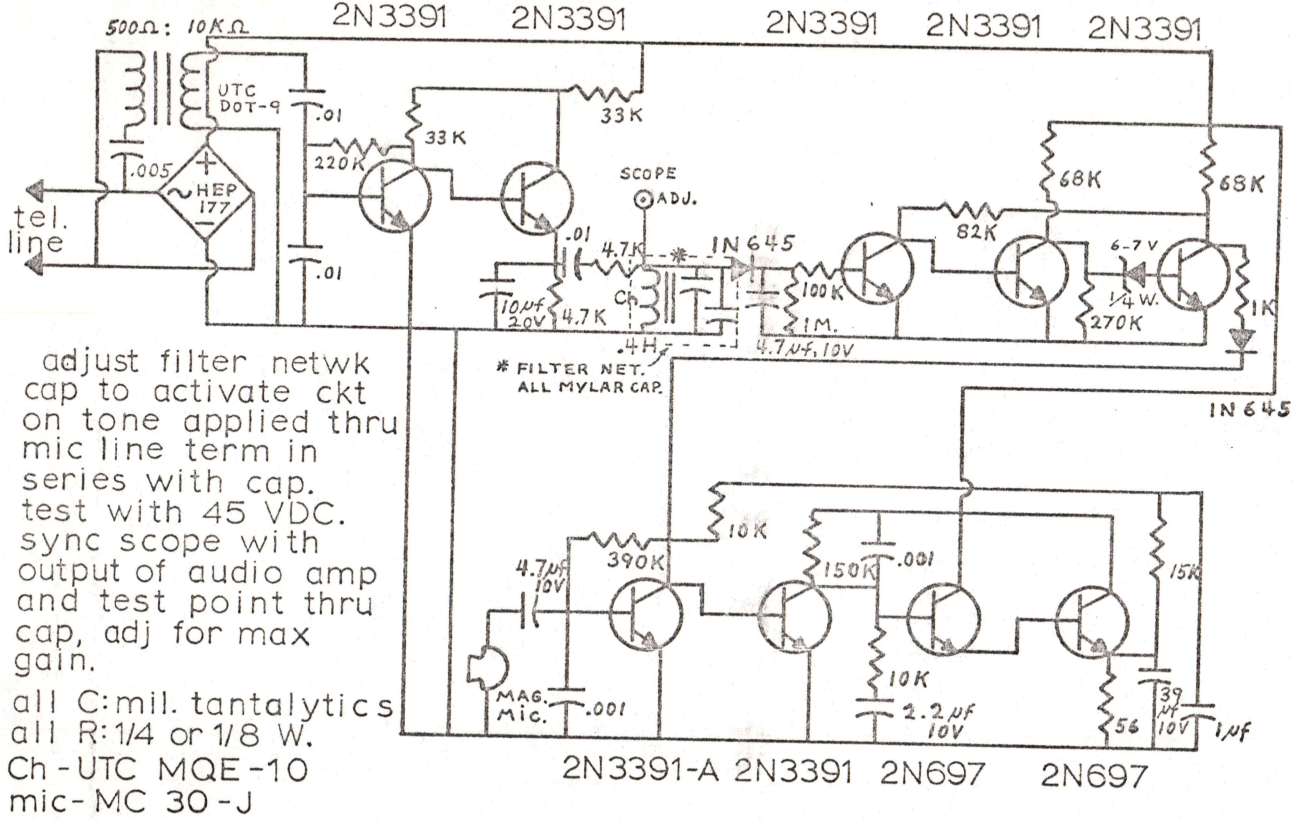


30-40 MHz	40-50 MHz
C2 - 15 to 20 pf	C2 - 10 to 20 pf
L1 - 7-3/4 to 8 t No. 24 enam.	L1 - 6-3/4 to 7 t No. 24 enam.
ant - 38"	ant - 37"

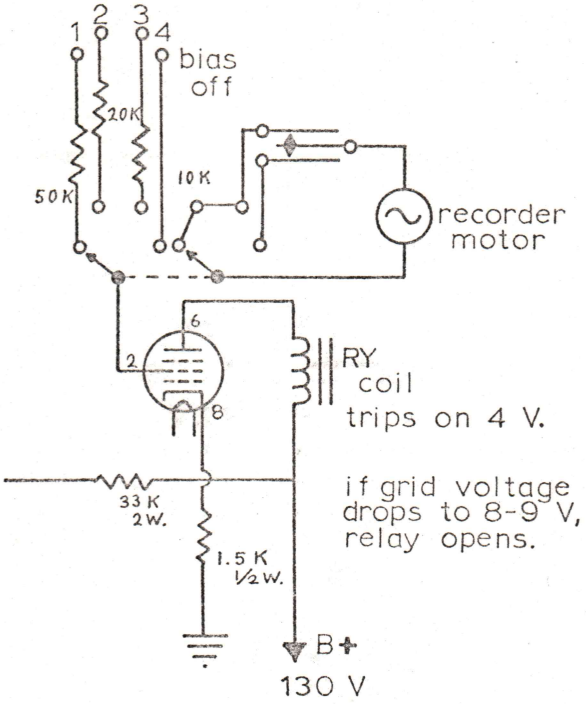
Appendix I-4. F-M telephone line transmitter, 30 to 40 MHz, 40 to 50 MHz, and 85 to 110 MHz, series-connected.



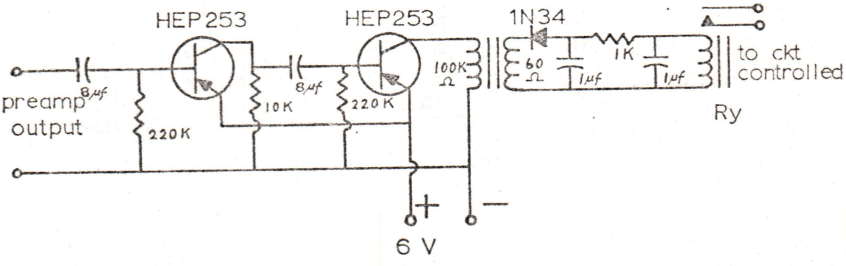
Appendix I-5. Adjustable audio band-pass filter network; when full on, passes 500 Hz to 2 kHz.



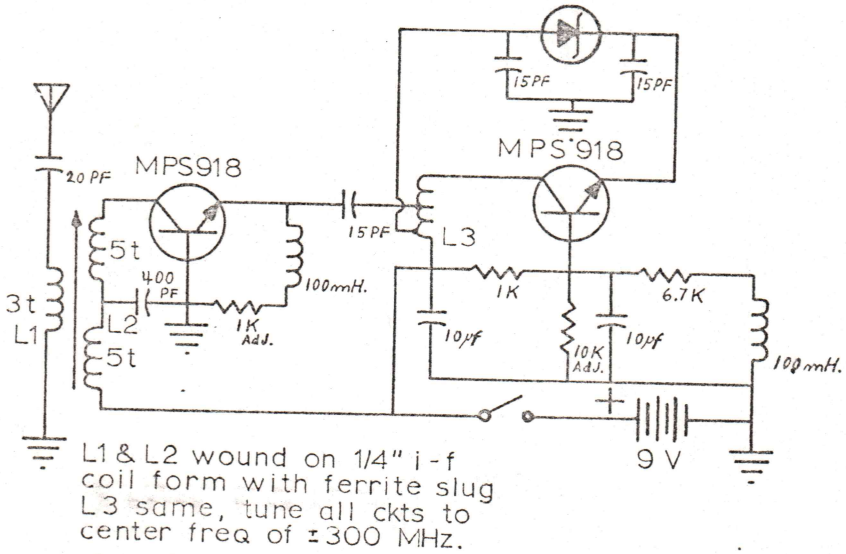
Appendix I-6. Audio-frequency activated monitor amplifier, line-powered by telephone line; also known as an infinity bug or transmitter.



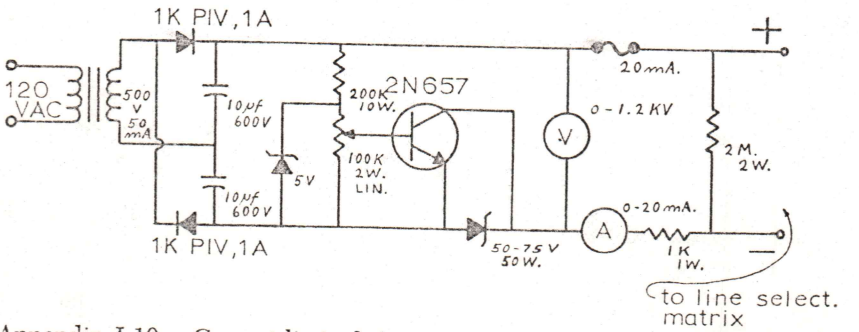
Appendix I-7. Separate telephone line relay with toll circuit.



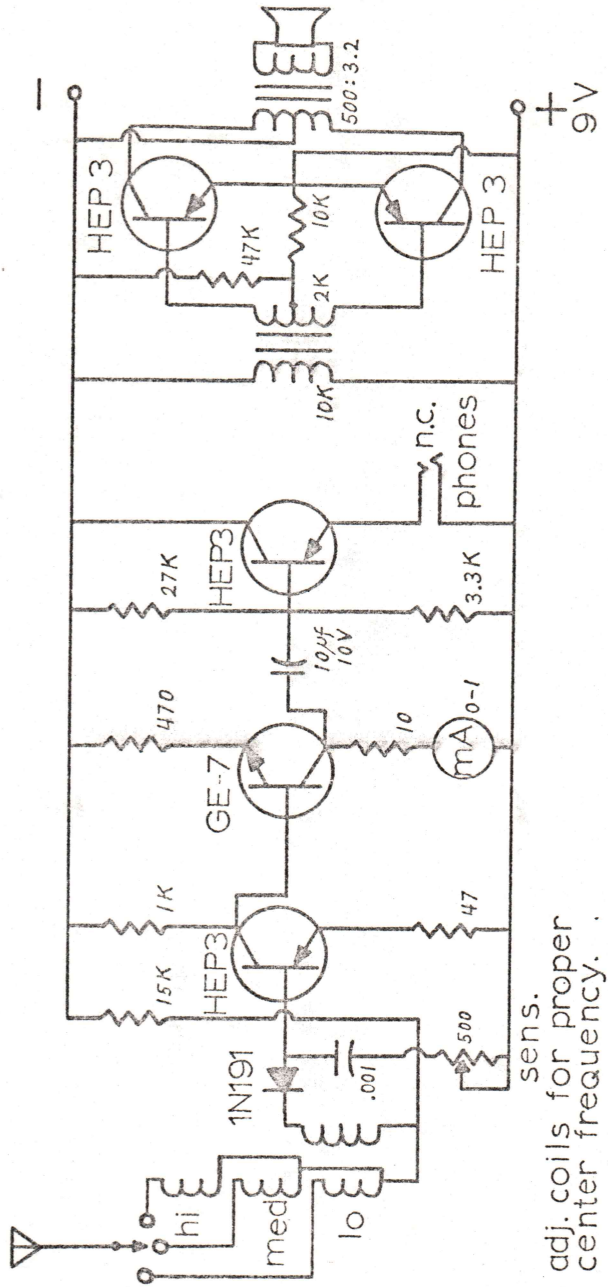
Appendix I-8. Signal-controlled switch.



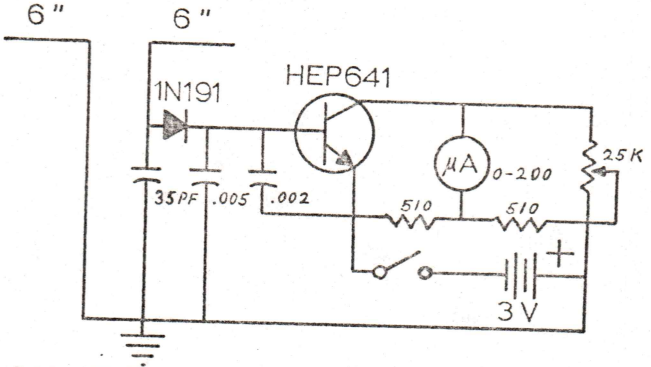
Appendix I-9. R-F noise generator; range 30 to 600 MHz.



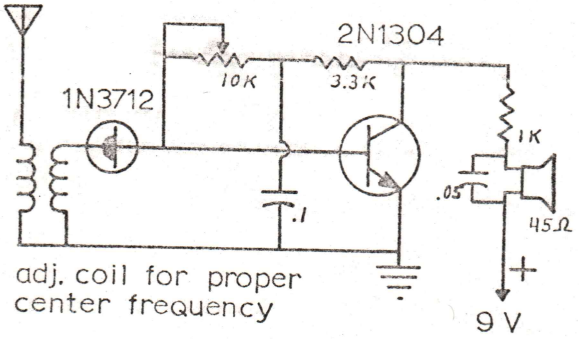
Appendix I-10. Current-limited (10 mA) power supply used in countermeasures checking of telephone subsets.



Appendix I-11. Field strength meter with additional amplification for feedback detection.

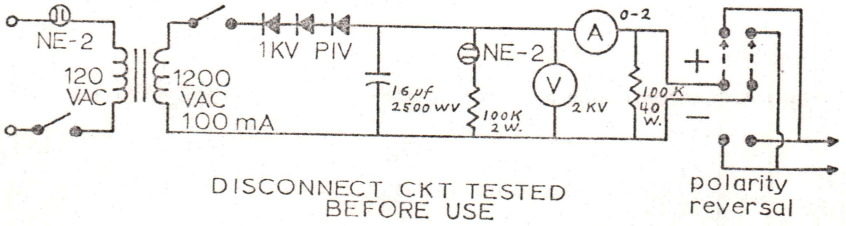


Appendix I-12. Field strength meter with dipole antenna for direction-finding.



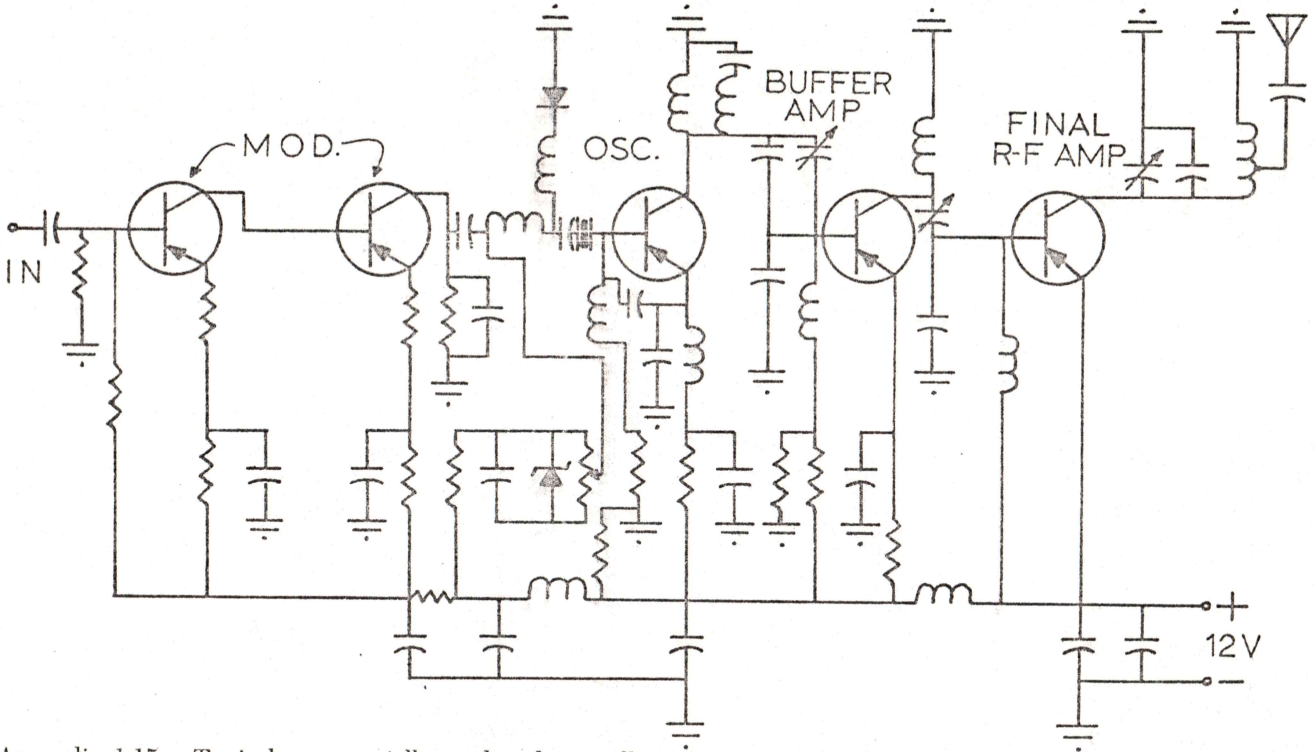
after G-E
appl. note

Appendix I-13. Field strength meter with sensitive tunnel diode circuit.



- MAY BE LETHAL -

Appendix I-14. High-voltage line destruction device used for destroying inaccessible line devices in place.



Appendix 1-15. Typical commercially-produced surveillance transmitter; this model not FCC-type accepted. Although sold only to law enforcement agencies, this unit was found in the office of an attorney dealing with civil service employees meet-and-confer negotiation not far from where it was manufactured in San Francisco. It had a range of approximately one city block.

Appendix II

GLOSSARY OF TERMS

Alarm signal. Device for indicating an abnormal line condition.

Armor. Steel tape wrapped over a lead sheath cable to protect the interior of the cable from outside forces.

Attenuation. A reduction in strength of transmitted signal, caused by line length and attenuator pads.

Audio-frequency (a-f). Frequencies that can be detected as sound by the human ear; range varies between 30 and 20,000 cycles per second.

B.S.P.'s—Bell System Practices. A set of orders issued by the telephone company, comparable to Army regulations; the "manual."

Backstrapping. A method by which telephones located at diverse points and listed in different names may be answered at a central point.

Balanced circuit. A divided circuit in which both sides are the same or in electrical balance.

Bird wire. A rubber-coated cable containing series of plastic-coated conductor wrapped over a center core of steel strand. Used to replace open wire lines in rural areas.

"Bliffy." A WECo No. 76A, B or C test set. In military usage known as the TS 420/V.

Body belt. Lineman's safety belt.

Bridge. A shunt path in an electrical circuit.

Bug. Electronic audio surveillance device; may be wired or wireless.

Bug detector. Electronic audio surveillance countermeasures device.

Bugging. Process of monitoring conversations by electronic means.

Bumper beeper. See Car beeper.

Butt steps. Removable steel pole steps that fit into lag bolts in a telephone pole. Used within six feet of the ground.

Buzzer. See Line tracer.

CMDE. Combination main distribution frame.

Cable. A series of pairs of color-coded plastic-jacketed wire, wrapped in paper and encased in lead sheath.

Can. Terminal box.

Can wrench. Terminal box wrench.

Capacitive pickup. A transducer that functions by the principle of capacitance, rather than by direct connection to a circuit.

Car beeper. Radio-frequency oscillator used for RDF tracking of automobiles; may be attached magnetically to undercarriage of the car.

Cavity resonator. Type of microwave transducer that modulates a microwave beam in the presence of audio frequencies. Exposed in the "Great Seal" U.S. Embassy Case, in 1960, as having been planted by the U.S.S.R.

Cheese box. An electronic device which may be set in action by a telephone call from a distant point and which would then, in effect, place persons who called the telephone in contact with a telephone in another location. Both telephones are ordinarily listed in the names of other persons.

Cleaning (House or office). Countermeasures operations.

Code-ringing. A telephone party line where the number of rings, the length of rings, or both, designate which telephone is being called.

Contact microphone. A microphone designed to be most sensitive to the physical vibrations of the surface upon which it is placed. See also Spike microphone.

Countermeasures. Defensive techniques designed to detect, prevent, or expose the use of electronic audio or visual surveillance devices.

Cover. The artificial pose assumed by an agent, his equipment or his operation.

Cross. A line fault; electrical contact between conductors of two different circuits.

Crosstalk. Intelligible sound heard in one transmission circuit as a result of transmission in another circuit; caused by capacitive and/or electromagnetic coupling.

Cut sheet. An order form to transfer service or to move drop wire from one terminal box to another.

Cutting over. Moving drop wire from one terminal box to another.

DASE. Defense against sound equipment. Electronic audio surveillance countermeasures.

Debugging. Process of conducting electronic audio surveillance countermeasures operations.

Directional microphone. A microphone that is extremely sensitive to audio frequencies arriving from one particular direction, while rejecting those that arrive from other directions.

Diversion. Secondary activity that screens or masks another activity, to reduce the "visibility" of the primary operation.

Door knob. WECo 105A Protector, used to furnish fuse protection and terminals to stations between poles.

Drop wire. Overhead wire connecting a subscriber's station with either cable or open wire.

Drop-in button. An in-line telephone radio transmitter concealed in a case that has the appearance of a telephone transmitter unit, such as the WECo F-1 transmitter unit.

Fault. A line open, cross, short, or ground; a defect in a wire circuit caused by a break in the circuit, a ground or a crossing or shorting of wires.

Feedback. Regeneration of a signal.

Field strength meter. An electronic radio field detection device that signals the presence of r-f energy, known as an "FSM."

Frameman. One who installs and solders wires in the central office frames.

Frames. Series of metal frames holding the intricate system of electrically actuated switches in the central office. working into the various crossbar switching arrangements. Also carry wire and cable between floors in the central office.

Gaffs. The sharp points of climbers. May be pole or tree gaffs.

Ground wire. Conductor leading from a device to a ground connection.

Grunt bag. Canvas bucket used to raise tools aloft. Used with handline.

Guy. A stranded steel cable ordinarily used to hold objects in place.

Handline. A line of ⅜ inch rope, usually 60 feet in length, with an eye on each end. May be used with a pulley clamped to the strand.

Harmonica bug. See Infinity bug.

Harmonics. Frequencies of exact multiples of a fundamental frequency.

Hinky. Nervous.

Hooks. Lineman's climbing irons.

House, or inside, wire. Inside station wire.

Hot mike. Activation of the microphone of a telephone in the "hung-up" position through the use of a third-wire tap an SCR, or with avalanche diodes. See also Third-wire tap.

Howler. See Screamer.

Inductive pickup. A transducer that functions by the principle of electromagnetic induction, rather than by direct connection to a circuit.

Infinity bug. An audio amplifier connected to a telephone line through an audio-tone sensitive relay which is activated by telephoning the bugged premises and sounding the coded tone. The called telephone does not ring and is held open so that the called can hear the conversations taking place in the vicinity of the microphone attached to the amplifier. May be hidden in the telephone or

somewhere else and fed to any point along the telephone line. Line-powered. Instead of the microphone, another telephone line may be monitored by the device. May be actuated by a coast-to-coast telephone call.

Infinity transmitter. See Infinity bug.

Inside plant. That part of a wire system which includes all switchboards, test boards, power supply, inside wiring and all associated equipment required for operating the inside equipment.

Installer. Telephone company employee who installs telephone equipment.

Jammer. An r-f or a-f generating oscillator that interferes with the operation of an electronic audio surveillance system.

Keyhole microphone. See Tube microphone.

Klein's. Lineman's pliers.

LDF. Line distribution frame.

Laser bugging. Electronic audio surveillance through the use of coherent light waves reflected from a surface vibrating at audio frequencies.

Line rig. Lineman's truck.

Line tracer. An audio-tone, or supersonic, generator used to trace out a particular subscriber's telephone pair from any number of other unknown pairs.

Locations. Binding post appearances.

Lose. To evade a surveillance.

MDF. Main distribution frame.

Ma Bell wrench. Spanner used by linemen.

Machine gun microphone. See Directional microphone.

Make (made). To recognize someone or something.

Megger. A resistance measuring device used for determining and locating line faults.

Monitoring. The act of listening-in (or supervising) on a line without causing interference.

Outside plant. That part of a telephone system which includes all lines and equipment used for installing and maintaining the lines outside the central office (CO).

PAX. Private automatic exchange.

PBX. Private branch exchange.

Parabolic microphone. See Directional microphone.

Parasite. An electronic device that when attached to a telephone receiving a direct-dial long distance call, precludes the registry of the call and subsequent toll charges.

Plant. (1) The physical location of the base for technical surveillance operations. (2) All equipment and line facilities installed and operated to provide telephone communications.

Protector. Device to protect equipment and personnel from foreign voltage, such as lightning.

Protector, open-space cut-out. Device consisting of two carbon blocks, one connected to one side of a line and the other to ground, separated by a narrow gap designed to provide a path to ground for high voltages, such as lightning.

RDF. Radio-direction-finding.

Repeater. Device for the re-transmission of a signal, ordinarily with amplification.

Ring-back tone. A signal tone transmitted to a calling party to show that the called telephone is being rung. Also known as audible ringing.

Rope (Roping). To lure or induce the subject of an investigation to believe a cover story or to participate in some activity which he believes is related to some other purpose.

"S" meter. Signal strength meter used on a radio receiver to indicate relative strength of signals received.

SMOE. Surreptitious methods of entry; the art of effecting entry into premises without leaving signs of such entry. Refined burglary. Acceptable when done by "friendlies"; felonious crime when done by enemies.

Scrambler. A speech-inversion and/or frequency-inversion device that codes audio frequencies so that they are not comprehensible to the unaided ear. May be used in either telephone or radio circuits. May be defeated through a-f spectrum analysis.

Screamer. An r-f detector, fed to an audio amplifier, that causes uncontrolled feedback when positioned near a concealed transmitter; hence, a-f "howler" or "screamer."

Selective ringing. Telephone party line ringing in which only the called telephone is rung.

Semiselective ringing. Telephone party line ringing in which two telephones are rung at the same time. Selection of the desired telephone accomplished by means of a one-ring, two-ring code.

Shake. To evade a surveillant.

Shotgun microphone. See Directional microphone.

Snake microphone. See Tube microphone.

Spike microphone. A contact microphone, usually employing a crystal element, which is affixed to a rod, or "spike," which passes through a wall to bear upon the inner wall, transmitting audio-frequency vibrations to the microphone using the wall as a diaphragm.

Splicer's furnace. Portable gas stove used to melt lead for re-soldering (wiping) cable sleeves.

Strand. Stranded steel wire used to support telephone cable; also known as cable messenger.

Strippers. Wire insulation strippers.

Subscriber line. Line between the central office and the subset; also known as the subscriber loop.

Superimposed ringing. Telephone party-line ringing employing a combination of a-c and d-c of both polarities to enable selective ringing.

Switchman. Employee handling transfer work in main office; bridges lines in central office.

Tailing. Process of conducting a surveillance of the activities of another.

Technical surveillance. Any combination of bugging, wiretapping, CCTV or radiolocation techniques.

Telephone set. A complete telephone equipment, including handset, ringer and all other associated parts located at a subscriber station with the exception of protective equipment.

Terminal strip. Block of insulating material to which a number of binding posts are fastened.

Test board (desk). Telephone switchboard, including testing apparatus, designed so that the telephone lines may be connected to testing equipment in the central office for evaluation.

Test set. (1) Lineman's test telephone handset; the "dumb bell," TS 365 G/T in the Signal Corps. (2) An item of telephone equipment used to locate faults and troubles in circuits or equipments.

Third-wire tap. The activating of a telephone microphone by adding a third wire to the circuit, so that the telephone microphone is active while the handset is "hung-up"; bypassing the hook-switch. See also Hot mike.

Toll. PBX and pay telephone station equipment.

Tool pouch. Green canvas tool bag, for carrying additional hand tools; snaps over lineman's body belt.

Tone. (1) See Line tracer. (2) A buzzer, or oscillator, tone test set. WECo 81A.

Tone bug. See Infinity bug.

Tube microphone. A microphone encased in a soundproof capsule from which projects a rigid or flexible tube of small diameter; this tube is the only passage to the microphone for sound waves.

Triangulation. Location of a transmitter by RDF methods.

Unbalanced circuit. A divided circuit in which both sides are unequal or in electrical imbalance.

Uncle Charlie. The Federal Communications Commission or any of its inspectors or field engineers.

Uncle Frank. The Federal Communications Commission or any of its inspectors of field engineers. See also Uncle Charlie.

Undercover. The process of conducting a discreet investigation while falsely assuming the identity of a third or nonexistent person.

VOX. Voice-operated switch.

Voice-frequency. Applied to the band of frequencies generated by the human voice and transmitted by a telephone circuit. Varies between 200 and 2,800 cycles over most domestic telephone lines.

"Wiggie." A voltohmmeter; also the slang for a "Wiggington" tester.

Wire sleeves. Nicopress sleeves used to splice drop wire.

Wiretap. A direct-connection telephone monitoring network.

Wireless wiretap. A radio transmitter connected to a telephone line by a matching network feeding its a-f input.

Wireless microphone. A miniature, flea-powered, radio transmitter.

Appendix III

ELECTRONIC COMPONENT DISTRIBUTORS

Allied-Radio Shack Electronics, 100 No. Western Ave., Chicago, Illinois 60680

American Geloso Electronics, Inc., 251 Park Ave., South, New York, New York 10010

Burstein-Applebee Co., 3199 Mercier St., Kansas City, Missouri 64111

Concord Electronics Corp., 1935 Armacost Ave., Los Angeles, California 90025

Edmund Scientific Co., Barrington, New Jersey 08007

Lafayette Radio & Electronics, 111 Jericho Turnpike, Syosset, Long Island, New York 11791

McGee Radio Co., 1901 McGee St., Kansas City, Missouri 64108

Olson Electronics, Inc., 260 So. Forge St., Akron, Ohio 44308

Appendix IV

MISCELLANEOUS ELECTRONIC TABLES

TABLE A-1

BELL SYSTEM

PIC Cable Color Code

Pair No.	*Ring*	*Tip*	*Binder Group No.*	*Pairs*	*Binder Colors*
1	BL	W	1	1-25	BL-W
2	O	W	2	26-50	O-W
3	G	W	3	51-75	G-W
4	BR	W	4	76-100	BR-W
5	S	W	5	101-125	S-W
6	BL	R	6	126-150	BL-R
7	O	R	7	151-175	O-R
8	G	R	8	176-200	G-R
9	BR	R	9	201-225	BR-R
10	S	R	10	226-250	S-R
11	BL	BK	11	251-275	BL-BK
12	O	BK	12	276-300	O-BK
13	G	BK	13	301-325	G-BK
14	BR-BK	BK	14	326-350	BR-BK
15	S	BK	15	351-375	S-BK
16	BL	Y	16	376-400	BL-Y
17	O	Y	17	401-425	O-Y
18	G	Y	18	426-450	G-Y
19	BR	Y	19	451-475	BR-Y
20	S	Y	20	476-500	S-Y
21	BL	V	21	501-525	BL-V
22	O	V	22	526-550	O-V
23	G	V	23	551-575	G-V
24	BR	V	24	576-600	BR-V
25	S	V	25	601-625	BL-W-R
			26	626-650	O-W-R
			27	651-675	G-W-R
			28	676-700	BR-W-R
			29	701-725	S-W-R
			30	726-750	BL-R-R
			31	751-775	O-R-R
			32	776-800	G-R-R
			33	801-825	BR-R-R
			34	826-850	S-R-R
			35	851-875	BL-BK-R
			36	876-900	O-BK-R

Abbreviations: BL (Blue), O (Orange), G (Green), BR (Brown), S (Slate), W (White), R (Red), BK (Black), Y (Yellow), V (Violet).

TABLE A-2

FLICKER TEST SET ROUTINE

Test	*Plugs*	*Switch*	*Leads*	*Steady*	*Light Flashing*	*None*
Shorts	A & T	Off	T & R	Short		No Short
Crosses (Bat.)	T & R	Off	BK in T to GRD RED in R to LUGS	Bat. X		No X
Grounds	A & T	Off	1 Clip to GRD other to LUGS	Ground		No Ground
Floaters T & R	C & D	On	1 Clip to GRD other to LUGS		Floater on T or R	
Floater Bridged	C & D	On	On T & R of pair		Bridged Floater	

TABLE A-3

LOOP ANTENNA FORMULA AND TABLE OF LENGTHS

$$L \text{ (length in feet)} = \frac{.16 \times 492}{f \text{ (MHz)}}$$

Sense Antenna: Start with four times the loop diameter and cut for a cardioid reception pattern.

f (MHz)	*L (ft)*	*f (MHz)*	*L (ft)*
175	0.45	50	1.57
170	0.46	49	1.61
165	0.48	48	1.64
160	0.49	47	1.67
155	0.51	46	1.71
150	0.53	45	1.75
		44	1.79
110	0.72	43	1.83
108	0.73	42	1.87
106	0.74	41	1.92
104	0.76	40	1.97
102	0.77	39	2.02
100	0.79	38	2.07
95	0.83	37	2.13
90	0.88	36	2.19
88	0.90	35	2.25
87	0.91	34	2.32
		33	2.39
76	1.04	32	2.46
75	1.05	31	2.54
74	1.06	30	2.62
73	1.08		
72	1.09	27	2.92
		26	3.03

The above listed frequencies are ones frequently used for automobile tailing transmitters, and the loop length shown is recommended for RDF use at that frequency. The sense antenna is employed to negate the 180 degree ambiguity inherent with the use of the unaided loop.

TABLE A-4

CONDUCTOR RESISTANCE

The resistance of gages of cable conductors ordinarily found in the subscriber loop plant are as shown:

Gage	*ohm/1K ft*	*ohms/mile of loop*
19	16.1	85
22	32.4	171
24	51.9	274
26	83.5	440

It should be noted that temperature is an important variable in the resistance of cable conductors. As the conductor becomes warmer, its resistance per foot increases. Conversely, as the conductor cools, its resistance per foot decreases and the number of feet per ohm increases. Mean resistance values of various conductor gages at different temperatures are shown in the table below:

Temperature	*Feet per ohm*			
F	*19-gage*	*22-gage*	*24-gage*	*26-gage*
0	142.6	70.9	44.2	27.6
10	139.9	69.5	43.4	27.0
20	137.2	68.2	42.5	26.5
30	134.5	66.8	41.7	26.0
40	131.8	65.5	40.9	25.5
50	129.1	64.2	40.0	24.9
60	126.4	62.8	39.2	24.4
70	123.7	61.5	38.4	23.9
80	120.9	60.1	37.5	23.4
90	118.2	58.8	36.6	22.8

TABLE A-5

TELEVISION FREQUENCY ASSIGNMENTS
(in MHz)

Channel	*Video*	*Audio*	*Limits*
2	55.25	59.75	54-60
3	61.25	65.75	60-66
4	67.25	71.75	66-72
5	77.25	81.75	76-82
6	83.25	87.75	82-88
7	175.25	179.75	174-180
8	181.25	185.75	180-186
9	187.25	191.75	186-192
10	193.25	197.75	192-198
11	199.25	203.75	198-204
12	205.25	209.75	204-210
13	211.25	215.75	210-216
14	471.25	475.75	470-476
15	477.25	481.75	476-482
16	483.25	487.75	482-488
17	489.25	493.75	488-494
18	495.25	499.75	494-500
19	501.25	505.75	500-506
20	507.25	511.75	506-512
21	513.25	517.75	512-518
22	519.25	523.75	518-524
23	525.25	529.75	524-530
24	531.25	535.75	530-536

TABLE A-5 (CONTINUED)

Channel	*Video*	*Audio*	*Limits*
25	537.25	541.75	536-542
26	543.25	547.75	542-548
27	549.25	553.75	548-554
28	555.25	559.75	554-560
29	561.25	565.75	560-566
30	567.25	571.75	566-572
31	573.25	577.75	572-578
32	579.25	583.75	578-584
33	585.25	589.75	584-590
34	591.25	595.75	590-596
35	597.25	601.75	596-602
36	603.25	607.75	602-608
37	609.25	613.75	608-614
38	615.25	619.75	614-620
39	621.25	625.75	620-626
40	627.25	631.75	626-632
41	633.25	637.75	632-638
42	639.25	643.75	638-644
43	645.25	649.75	644-650
44	651.25	655.75	650-656
45	657.25	661.75	656-662
46	663.25	667.75	662-668
47	669.25	673.75	668-674
48	675.25	679.75	674-680
49	681.25	685.75	680-686
50	687.25	691.75	686-692
51	693.25	697.75	692-698
52	699.25	703.75	698-704
53	705.25	709.75	704-710
54	711.25	715.75	710-716
55	717.25	721.75	716-722
56	723.25	727.75	722-728
57	729.25	733.75	728-734
58	735.25	739.75	734-740
59	741.25	745.75	740-746
60	747.25	741.75	746-752
61	753.25	757.75	752-758
62	759.25	763.75	758-764
63	765.25	769.75	764-770
64	771.25	775.75	770-776
65	777.25	781.75	776-782
66	783.25	787.75	782-788
67	789.25	793.75	788-794
68	795.25	799.75	794-800
69	801.25	805.75	800-806
70	807.25	811.75	806-812
71	813.25	817.75	812-818
72	819.25	823.75	818-824
73	825.25	829.75	824-830
74	831.25	835.75	830-836
75	837.25	841.75	836-842
76	843.25	847.75	842-848
77	849.25	853.75	848-854
78	855.25	859.75	854-860
79	861.25	865-75	860-866
80	867.25	871.75	866-872
81	873.25	877.75	872.878
82	879.25	883.75	878-884
83	885.25	889.75	884-890

Appendix V

WORLD LOW-VOLTAGE POWER SUPPLIES

TABLE A-6

LOW-VOLTAGE POWER SUPPLIES OF THE WORLD

Territory (freq) Voltage

ASIA

Aden (50) 230/240
Afghanistan (50) 220/380
Burma (50) 230
Cambodia (50) 120/208; some 220/380
Ceylon (50) 230/400
Cyprus (50) 240
Hong Kong (50) 200/346
India (50) 230/400 and others, some dc
Indonesia (50) 127/220
Iran (50) 220/380
Iraq (50) 220/380
Israel (50) 230/400
Japan (50, 60) 100/200
Jordan (50) 220/380
Korea (60) 100/200
Kuwait (50) 250/415
Laos (50) 127/220; some 220/380
Lebanon (50) 110/190; some 220/380
Malaya (50) 230/400; some 240/415
Nepal (50) 110/220
Okinawa (60) 110/240
Pakistan (50) 230/400 and others, some dc
Philippines (60) 110, 220, and others
Saudi Arabia (50, 60) 120/208; also 220/380, 230/400
Singapore (50) 230/400
Syria (50) 115/200; some 220/380
Taiwan (60) 100/200
Thailand (50) 220/380; also 110/190
Vietnam (50) 220/380 future standard
Yemen (50) 220

AFRICA

Algeria (50) 127/220, 220/380
Angola (50) 220/380
Congo (50) 220/380
Dahomey (50) 220/380
Ethiopia (50) 220/380; some 127/220
Guinea (50) 220/380; some 127/220
Kenya (50) 240/415
Liberia (60) 120/240
Libya (50) 125/220; some 230/400

TABLE A-6 (CONTINUED)

Territory (freq) Voltage

Mali (50) 220/380; some 127/220
Mauritius (50) 230/400
Morocco (50) 115/200; also 230/400 and others
Mozambique (50) 220/380
Niger (50) 220/380
Nigeria (50) 230/400
Rhodesia (50) 220/380; also 230/400
Senegal (50) 127/220
Sierra Leone (50) 230/400
Somalia (50) 220/400; also 110, 230
South Africa (50) 220/380; also others, some dc
Sudan (50) 240/415
Tanganyika (50) 230/400
Tunisia (50) 220/380; also others
Uganda (50) 240/415
United Arab Republic (50) 110, 220, and others; some dc
Upper Volta (50) 220/380

EUROPE

Austria (50) 220/380; Vienna also has 220/440 dc
Azores (50) 220/380
Belgium (50) 220/380, many others; some dc
Canary Islands (50) 127/220
Denmark (50) 220/380; also 220/440 dc
Finland (50) 220/380
France (50) 120/240, 220/380, and many others
Germany, Federal Republic (50) 220/380; also others, some dc
Gibralter (50) 240/415
Greece (50) 220/380; also others, some dc
Iceland (50) 220; some 220/380
Ireland (50) 220/380; some 220/440 dc
Italy (50) 127/220, 220/380 and others
Luxembourg (50) 110/190, 220/380
Madeira (50) 220/380; also 220/440 dc
Malta (50) 240/415
Monaco (50) 127/220, 220/380
Netherlands (50) 220/380; also 127/220
Norway (50) 230
Portugal (50) 220/380; some 110/190
Spain (50) 127/220; also 220/380, some dc
Sweden (50) 127/220, 220/380; some dc
Switzerland (50) 220/380
Turkey (50) 220/380; some 110/190
United Kingdom (50) 240/415 and others, some dc
Yugoslavia (50) 220/380

NORTH AMERICA

Alaska (60) 120/240
Bermuda (60) 115/230; some 120/208
British Honduras (60) 110/220
Canada(60) 120/240; some 115/230
Costa Rica (60) 110/220
El Salvador (60) 110/220
Guatemala (60) 110/240; some 220, 120/208
Honduras (60) 110/220
Mexico (50, 60) 127/220 and others; Mexico City (50) 125/216
Nicaragua (60) 120
Panama (60) 110/220; some 120/240, 115/230
United States (60) 120/240 and 120/208

TABLE A-6 (CONTINUED)

Territory (freq) Voltage

OCEANIA
Australia (50) 240/415; also others and dc
Fiji Islands (50) 240/415
Hawaii (60) 120/240
New Caledonia (50) 220/440
New Zealand (50) 230/400

SOUTH AMERICA
Argentina (50) 220/380; also 220/440 dc
Bolivia (50, 60) 220 and others
Brazil (50, 60) 110, 220; also others and dc; Rio de Janeiro (50) 125/216
British Guiana (50, 60) 110/220
Chile (50) 220/380; some 220 dc
Colombia (60) 110/220; also 120/240 and others
Ecuador (60) 120/208; also 110/220 and others
French Guiana (50) 127/220
Paraguay (50) 220/440; some 220/440 dc
Peru (60) 220; some 110
Surinam (50, 60) 127/220; some 115/230
Uruguay (50) 220
Venezuela (60, some 50) 120/208, 120/240

WEST INDIES
Antigua (60) 230/400
Bahamas (60) 115/200, some 115/220
Barbados (50) 120/208 some 110/200
Cuba (60) 115/230; some 120/208
Dominican Republic (60) 115/230
Guadeloupe (50) 127/220
Jamaica (50, some 60) 110/220
Martinique (50) 127/220
Puerto Rico (60) 120/240
Trinidad (60) 115/230
Virgin Islands (60) 120/240

Note: All voltages a-c unless stated specifically as d-c. Listings show residential electric power in each country; in many other cases differences exist, for which see the abstracted document.

This material abstracted from *Electric Power Abroad*, Bureau of International Commerce, U.S. Department of Commerce, Washington, D.C., 1963.

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2. Ampex Corp., Park Ridge, Illinois (Magnetic audio and video tape recorders)
3. Amphenol, Inc., Broadview, Illinois (Surveillance transmitters)
4. Clifton, R. B., Miami, Florida (General surveillance)
5. Cobra Electronics, San Antonio, Texas (Pocket F-M receivers)
6. Comrex Corp., West Concord, Massachusetts (Surveillance transmitters)
7. Continental Electronics and Sound Co., Dayton, Ohio (Telephone devices)
8. Defense Electronics, Inc., Rockville, Maryland (VHF surveillance and CM receiver)
9. Delcon Division of Hewlett-Packard Co., Palo Alto, California (Telephone scramblers)
10. Dictation Products, Ltd., Hallandale, Florida (Microphones)
11. Edwards Engineering Co., Port Washington, New York (Pocket stereo recorder)
12. General Electric Corp. Comm. Products Dept., Lynchburg, Virginia (F-M transceivers)
13. Honeywell, Test Instruments Division, Denver, Colorado (VHF surveillance CM receiver)

14. Kel Co., Belmont, Massachusetts (The "Kel Kit") General surveillance)
15. Kinematix, Inc., Chicago, Illinois (Surveillance transmitters)
16. Magnasync Corp., North Hollywood, California (Logging tape recorders)
17. Mieco, Inc., Timonium, Maryland (Telephone and radio scramblers)
18. Mosler Research Products, Inc., Danbury, Connecticut. Formerly Research Products, Inc. (The "Schmidt Kit") (General surveillance)
19. Motorola, Inc., Burlingame, California (F-M receiver-transmitter components)
20. Radio Specialties Mfg. Co., Portland, Oregon (F-M receiver-transmitter components)
21. Regency Electronics, Inc., Indianapolis, Indiana (F-M radio receivers)
22. Shure Brothers, Evanston, Illinois (Microphones)
23. Sinclair Radio Laboratories, Inc., Tonawanda, New York (Surveillance antenna)
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